Concrete

Vol. 29 Chicago, August, 1926 No. 2

Old and New Ideas on Control of Strength of Concrete

A Plain, Practical Discussion of the Factors That Affect the Strength of Concrete—Theories Explained—Putting Them Into Effect on the Job—How to Control the Variables That Affect the Strength of Concrete

By JOHN G. AHLERS*

Concrete is not controlled in strength by proportion of cement to sand and stone, but by ratio of cement to water only. The addition of sand and stone, or gravel, only makes the concrete more economical or less economical, depending on whether much or little is added, or depending whether the sand and stone are well or poorly graded. The results of 100,000 tests at Lewis Institute prove this statement.

Although unknown to many of us at that time, we now know that all concrete produced in the past was strong in proportion as more or less water was used with the cement, and not because of any proportions of cement to fine and coarse aggregate. It was merely because we used less water when using less aggregate that our concrete was stronger.

When we control concrete for strength by means of the water-ratio theory we must discard our old conception that good or bad concrete depended upon fixed proportions of cement to sand and stone without regard to the amount of water used. In fact, we must consider concrete as so much water-cement paste swelled up and filled out with inert sand and stone filler grains for the sole purpose of economy.

When engineers and contractors both approach this problem they can profitably keep these two ideas separate —the engineer can confine *his* efforts and attention to that of *strength* as controlled by the water-cement ratio; and the contractor can confine *his* efforts and attention to the *grading and quality of the aggregate* so as to enable him to add as much aggregate as possible while still leaving the resulting concrete workable and plastic.

It is the confusing of these two distinct and separate phases — strength and economy — that causes misunderstandings and creates opposition to the new methods developed by the Portland Cement Association and other progressive engineers. We still hear, and probably will in the future, the statement that strength of concrete is affected by a poor grading of stone or sand; and this idea must be discarded before concrete can be controlled successfully by the water-ratio method.

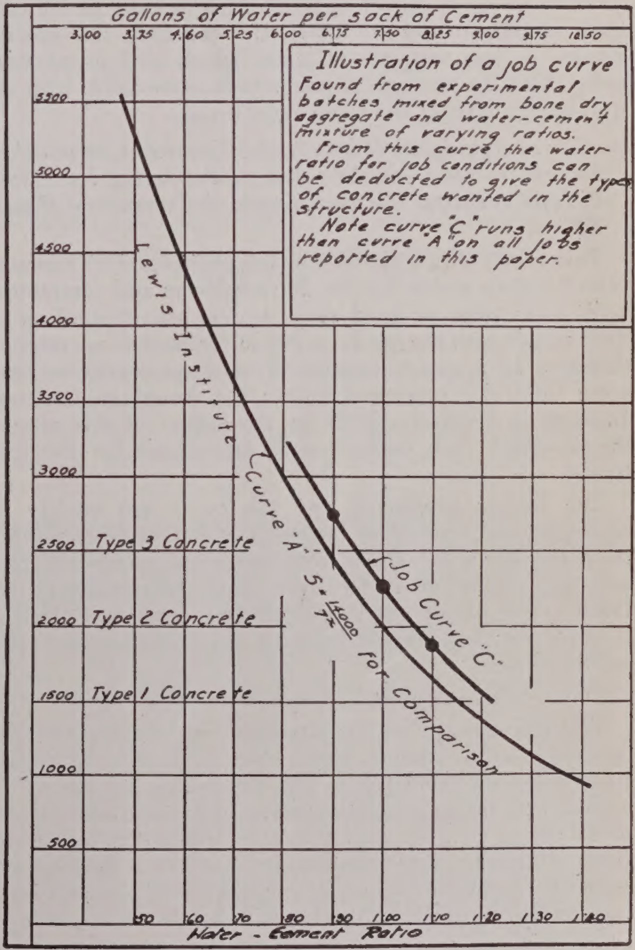


Illustration of a job curve

Found from experimental batches mixed from bone dry aggregate and water-cement mixture of varying ratios.

From this curve the water-ratio for job conditions can be deducted to give the types of concrete wanted in the structure.

Note curve "C" runs higher than curve "A" on all jobs reported in this paper.

Fig. 1.—Job curve derived from experimental batches of bone-dry aggregate and varying water-cement ratios

---

*Presented before the Affiliated Technical Societies of Boston, April 21, 1926.

Grading and Quantity of Aggregate Control Economy or Yield of Concrete and Affect Yield Only, having No Connection with Strength as long as Concrete is Plastic.

Contractor's Viewpoint.—The contractor will soon learn that good grading of sand and good grading of stone are essential to get a high yield in the concrete, for when the amount of water per bag of cement is fixed, there will be no other means of securing economy and high yield. The engineer should allow him to work this out for himself. There is plenty of literature and information available by which he can study and evaluate his aggregate; or he can by actual trial find the most workable plastic mix producing the greatest amount of concrete for a given amount of water and cement, by mixing different kinds of sand and stone available in various proportions and noting the results. When he reaches this stage the engineer can aid him by making a series of cylinders of the concrete that the contractor wishes to use.

The Water-Cement Ratio $\frac{W}{C}$ *— Controls the Strength of Concrete and Affects Strength Only*

Engineer's Function.—The question of strength is the only one with which the engineer should be greatly concerned. Having a given job condition and method of operation, a definite grade of cement, and a certain kind of aggregate that the contractor wishes to use, the engineer can determine exactly what strength results from these for a water-cement ratio of "one." When once the so-called "job constant" is established from the water-cement ratio of "one," for the materials to be used (regardless of the quantity of sand, gravel or mix), then as long as the concrete is plastic and workable, the engineer can specify greater or less amounts of water which will proportionately affect the strength of concrete in accordance with the well-known laws of the water-ratio theory.

Quality of Aggregates (Cleanliness, Chemical Composition, Soundness, etc.) has the Effect of Producing Variations in Job Curves for the Same Grade of Cement and Water-Ratios.

This factor which enters into the production of concrete is well known and is the one that engineers and contractors refer to as poor or good sand, and is usually tied up in their minds with the grading, but in reality has no relation thereto. In a paper, entitled "New Experiences in Concrete Control," presented before the American Concrete Institute in February, 1926, by the author of this article, the so-called "job curves" were introduced for the first time.

The factors producing any job curve are quality of aggregate and quality of cement. A job curve is plotted from the strengths of concrete specimens produced from any job operation under different water-cement ratios. Once a few points are found on this curve, any desired strength may be obtained by using the corresponding ratio on the curve.

Lately I have proposed another term—"job constant."

The job constant is the strength obtained on any job operation with a water-cement ratio of "one." This constant will vary from job to job, depending on *quality* of cement and aggregate used, method of manipulation (time of mixing), etc., but will not vary within the job itself. Once established and occasionally verified, it furnishes a sound guide for uniform concrete when water-cement ratio is carefully controlled from batch to batch.

Variables Affecting Strength

We always have the following variables to consider when making concrete: (1) quality of cement; (2) quality of aggregate; (3) quantity of aggregate; (4) quantity of water; (5) quantity of cement.

Let us see how these variables enter into our problem of economical concrete and how we can control them simply and therefore make a uniform low-cost product and help the whole industry.

First and second are the *quantity of the cement and aggregate.* These two will not vary much within the job itself. They establish the above-mentioned job curve and job constant. The engineer and contractor can control them by buying "high testing" cement and clean, sharp sand and gravel or stone; but once materials are furnished to an operation they do not enter into our problem of job control.

Third is the *quantity of aggregate* and, as has been stated previously, the variation in grading and quantity does not affect the strength as long as the resulting concrete is workable and plastic (slump from 4 to 8 inches). The amount used per batch should, of course, be controlled and constant. It is also necessary to watch the grading, since it affects the economy of the resulting mix, although it may not influence the strength of the concrete.

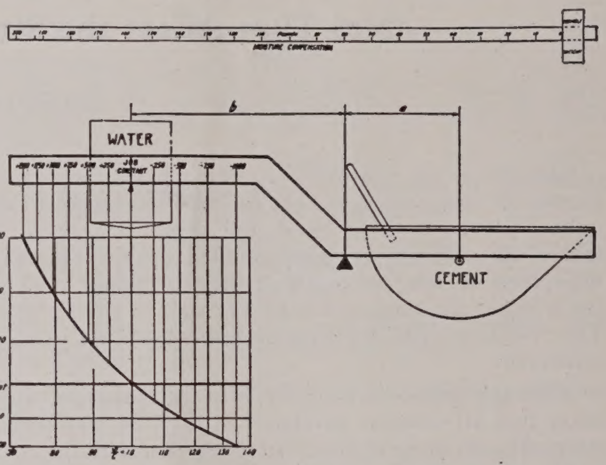


Fig. 2.—Diagrammatic sketch of Ahlers Concrete strength regulator

$$\text{The curve is } S = \frac{14000}{A^x}$$

$$x = \frac{W}{C} = \frac{a}{b} \text{ by weight. For } \frac{W}{C} = 1, \frac{a}{b} = \frac{62.5}{94.0} \text{ lbs.} = \frac{2}{3} \text{ by weight}$$

The *workability* is affected, also, by the quantity of the aggregate, but does not affect the strength of the concrete when kept controlled within the forementioned limits of slump.

With regard to the fourth and fifth variables (quantity of water and cement) we need a simple method of regulating these exactly and hence controlling all variables. A "concrete strength regulator" has been developed for this purpose.

The so-called "strength regulator" is in reality a contractor's job tool. It has now been used on ten different building operations and has given remarkably uniform and economical results. We would not consider getting along without it. Every batch comes out the same and is of the same strength because *all* inequalities of cement volume are automatically compensated for by the water. With the moisture in aggregate allowed for along the line of maximum average, every batch of concrete must be as strong as, or stronger than, desired.

Too much stress cannot be placed on the economy resulting from uniformity of batch after batch of concrete. Each output of the mixer will have the ultimate amount of aggregate present, controlled only by workability, and this gives remarkable results in economy, as facts shown later will confirm.

The fourth variable is the *quantity of water*. It may be noted, by a study of the water-ratio curves, that errors in measuring water as small as three quarts in a two-bag batch will affect the strength of concrete as much as 200 lbs. per sq. in. at 28 days.

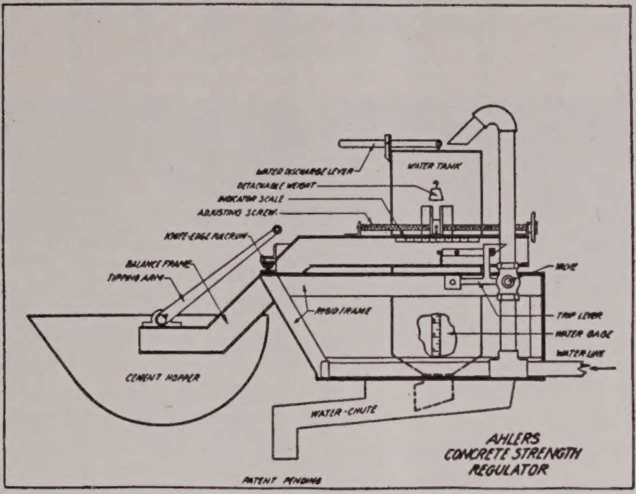


Fig. 3.—Sectional View of Regulator

There are two conditions that change the amount of water to each batch: (*a*) moisture in aggregate; (*b*) irregularity in measuring apparatus.

Moisture in Aggregate.—Variations due to moisture content of the aggregate are not as great as commonly assumed. Various test data attached hereto show that this variation runs from 1½ to 2½ per cent, or that the variation is usually not greater than half of 1 per cent.

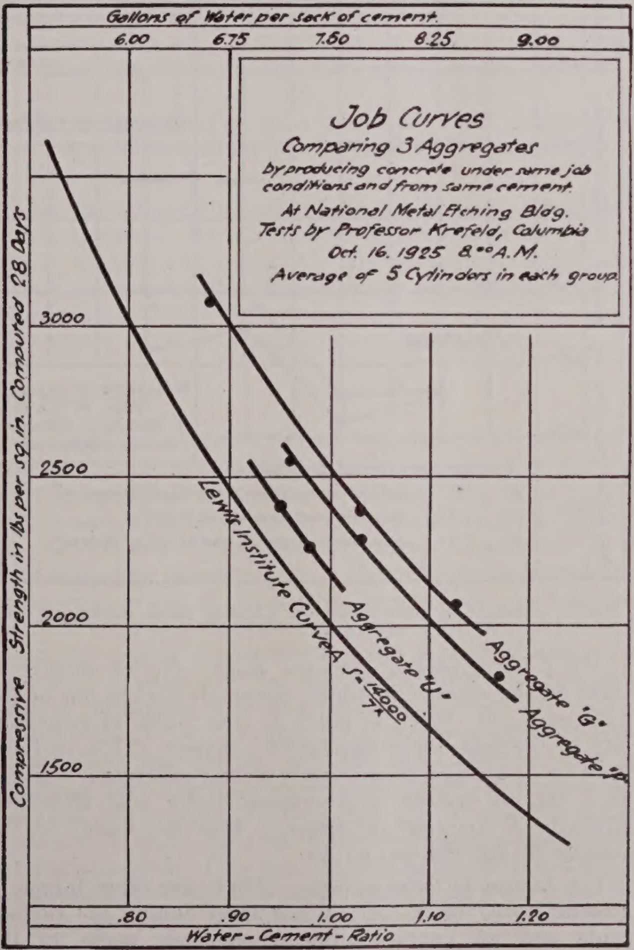


Fig. 4.—Job curve comparing three aggregates

By adopting what in the paper before the American Concrete Institute was termed a "*maximum average*" from the results of tests made on the job, we are always on the safe side, and the batches that are running drier than this assumed "*maximum average*" have a strength a little higher than anticipated. This is borne out by actual test results, as shown on attached diagrams. (Figs. 5, 6 and 7.)

Batch Number	Actual 7-Day Strengths (Lbs. per Sq. In.)	Computed 28-Day Strengths (Lbs. per Sq. In.)	Actual 28-Day Strengths (Lbs. per Sq. In.)	Per Cent Lower than Actual 28-Day Strengths	Per Cent Higher than Actual 28-Day Strengths
3	671	1,450	1,480	2.0	–
3	666	1,441	1,485	7.5	–
3	586	1,312			
5	765	1,595	1,810	15.2	–
5	732	1,545			
5	683	1,468	1,600	12.1	–
8	805	1,657	1,860	9.2	–
8	770	1,604	2,000	16.7	–
8	785	1,626			
12	1,385	2,490	2,420	–	2.8
12	1,350	2,452	1,970	–	15.7
12	1,190	2,225			
15	1,080	2,067	2,190	5.6	–
15	1,267	2,335	2.330	7.5	–
15	1,018	1,975			
18	1,356	2,460	2,490	1.2	–
18	1,286	2,361	2,470	3.8	–
18	1,306	2,390			
21	1,343	2,443	2,890	15.4	–
21	1,202	2,242	2,900	21.6	–
21	1,244	2,303			
23	1,000	1,950	2,840	31.2	–
23	1,112	2,112	2,660	21.7	–
23	1,062	2,050			
25	1,290	2,367	2,630	10.0	–
25	1,242	2,300	2,820	19.4	–
25	1,203	2,243			
28	1,083	2,071	2,240	7.6	–
28	1,144	2,160	2,440	11.5	–
28	1,146	2,160			
Average	1,059	2,028	2,276	12.0	9.2

7-day and 28-day cylinders were made out of same samplerfull. Bracketed results indicate that the average of these was used for comparison with 28-day results.

Comparison between 7-day and 28-day cylinders. Tests of October 16, 1925

The amount of aggregate per batch may be varied to produce the desired workability of the concrete, provided compensation be made for the additional amount of moisture that is added or subtracted in this manner.

Irregularity in Measuring Apparatus.—Irregularities in measuring the water are well known, of common occurrence, and have been ignored too much in the past. There

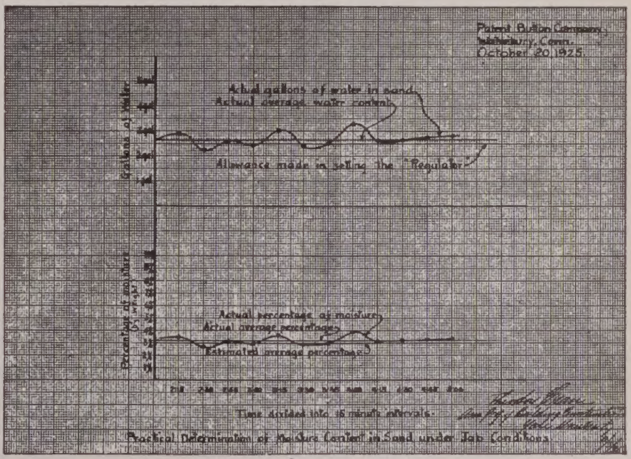


Fig. 5.—Moisture content of sand under job conditions—Patent Button Company

are good appliances available for measuring water, but they are expensive and get out of order easily. The average "mixer man" is impatient and must be given an easily understood way of measuring the water. If the water can be weighed automatically in accordance with, or depending upon, the amount of cement, this is an ideal arrangement. Usually we see measuring tanks put aside, and the good old pail or water barrel substituted. When we realize, as above stated, that three quarts of water in a two-bag batch changes the strength of resulting concrete 200 lbs. per sq. in., it is small wonder that under the old methods we needed large factors of safety and demanded very rich concrete in order to be on the safe side. It appears, however, that we are approaching the day when this variable can be overcome in a simple way on every job. The "inundator" is a step in the right direction. The device described below is believed to be a simpler and better method.

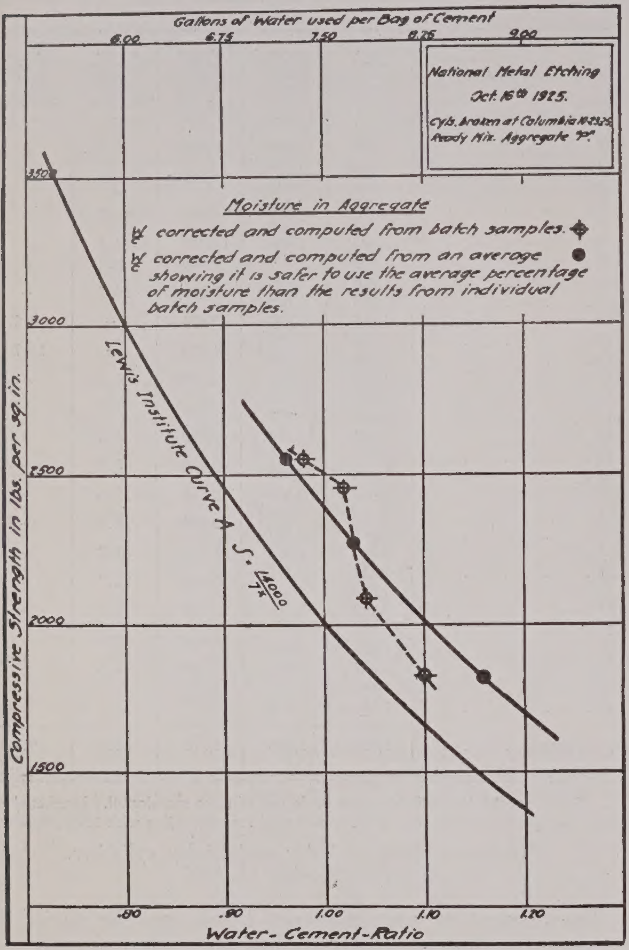


Fig. 6.—Moisture content of aggregate used in national metal etching job

Fifth is the *quantity of cement* added to each batch. This is a much more serious variable than commonly known or considered. It should be noted that the following variations may take place in *every* batch:

(*a*) *Change of Weight of Cement Bags.*—Table 3, included in this article, shows weights of 100 bags of cement weighed consecutively from the stock pile on a recent job, just as they would run going into the mixer. The weights show a variation of as much as 10 lbs. from high to low. The average is in exact accordance with the weight commonly assumed (94 lbs. net). The variation of 5 lbs. in a one-bag batch will cause a change in strength of 400 lbs. per sq. in., as shown by the water-ratio curve. This factor must be considered if absolute control of strength of concrete is desired. This variation is probably caused by the men at the cement mills filling the bags on a piecework basis. There should be an adjustment for this variable in every batch of concrete, if possible.

Table 3.—Weights of 100 cement bags in pounds; weighed consecutively on April 20, 1926, as run of stock pile, Macy job, Long Island City, N. Y.

97	94	94	97	94	94	96	95	98	100
93	96	97	94	99	94	94	94	93	90
93	93	93	97	97	95	91	93	101	98
94	98	91	96	94	95	96	94	98	96
95	97	98	95	95	94	93	97	93	99
97	98	98	97	95	95	95	98	92	96
95	97	93	95	94	95	94	93	93	92
98	93	94	92	95	94	96	95	94	100
96	94	93	95	93	93	93	98	93	92
98	99	95	95	91	98	97	95	97	95

Greatest variation between any four bags taken consecutively	10 lbs.
Greatest variation between any two bags	11 lbs.
Average weight per bag	95 lbs.
Average weight of empty sack	1 lb.

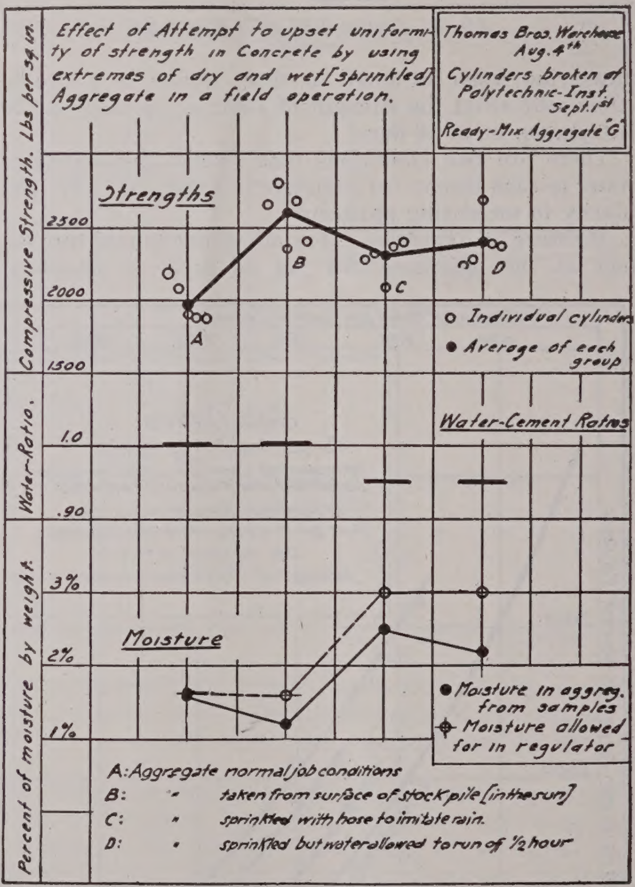


Fig. 7.—Results of tests made on Thomas Bros. warehouse job

(*b*) *Change Due to Shaking Bags.*—Notice should be taken of the manner in which cement is shaken out of the bags on a job. Often as much as 2 or 3 lbs. of cement is left in the bag when improperly shaken. This variable must be considered if uniformly strong concrete is wanted, as 2 lbs. of cement in a one-bag batch will affect the strength of concrete (if water is kept the same) to the amount of 160 lbs. per sq. in.

(*c*) *Lumps in Cement Bags.*—There are often lumps in cement stored on a job. When these lumps are thrown aside and no corresponding corrections made in the amount of water, a serious change takes place in the expected strength of the concrete in the batch. This variable should be controlled in some manner.

(*d*) *Torn Bags.*—Many torn bags come on the mixer platform and cement is also spilled around on the mixer platform as well as in the storage shed. If this is not compensated for, other changes in the strength of the concrete will be occasioned thereby.

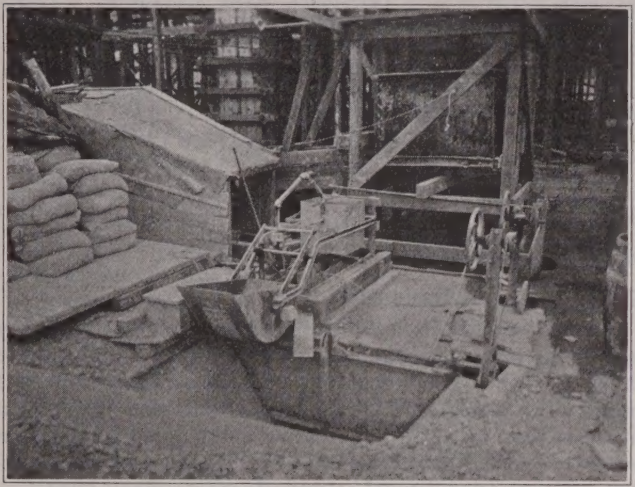


Fig. 8.—Ahlers concrete strength regulator

There is, therefore, a great necessity for refinement in controlling these variables. All these are very serious, and the control of them may seem to present unsurmountable difficulties. However, they can all be overcome by a very simple arrangement on the job.

It will be noted that the refinement really needed is the control of the water-cement ratio itself, or the factor $\frac{W}{C}$. If this can be controlled on a laboratory basis on the large scale required at a mixer plant, resulting uniform concrete should be obtained.

The necessity, therefore, of an easily used laboratory tool is apparent. Such a tool or device, shown on Figs. 3 and 8, is simple in operation, has no moving parts, and cannot get out of order. The diagram showing the appplication of this device demonstrates further the exactness of the working of the water-ratio control on the job.

Job Constant

As previously stated, every aggregate has its own strength value when combined with a given brand of cement, regardless of how much or how little of the aggregate is used, as long as we fix the ratio of water to cement. To establish this "job constant," using a "regulator," it is only necessary to run, early in the job, many batches of water and cement at the fixed ratio and then combine the mixture with any desirable quantity of coarse and fine aggregate to give the workability the contractor and engineer wish to secure. Note on diagram that this job constant is considered best established at or near the water-cement ratio of "one," as this is commonly assumed to give about 2,000 lbs. per sq. in. We find, however, that it usually gives a higher strength than 2,000 lbs. because we use clean, sharp sand. It may give a lower strength if the aggregate is poor in quality and the cement not of the highest standard. This job constant must be established, however, and when once established it is a very simple thing to go higher and lower in the scale of strength to get exactly the strength desired for the particular part of the structure.

Elimination of All Variables

As may be seen from this diagram, by a simple sliding of a weight, the amount of moisture that is present in the aggregate (which is easily computed) can be compensated for directly on the balance, omitting an amount of water equal to that which is already in the aggregate.

As stated above, and confirmed by other investigations, the percentage of moisture runs very uniform throughout any one day's operation and under any given weather condition.

Comparison of Results under (a) Old Method, (b) Job System of Exact Laboratory Method, (c) Construction of Portland Cement Association Building, Chicago

Let us now compare the results in strength under such a basis of control with those obtained by other means. Note in the diagrams of curves attached, marked Job 195, how nearly the strength runs to a predetermined line, following actually parallel to the water-cement ratio as adjusted on the Regulator.

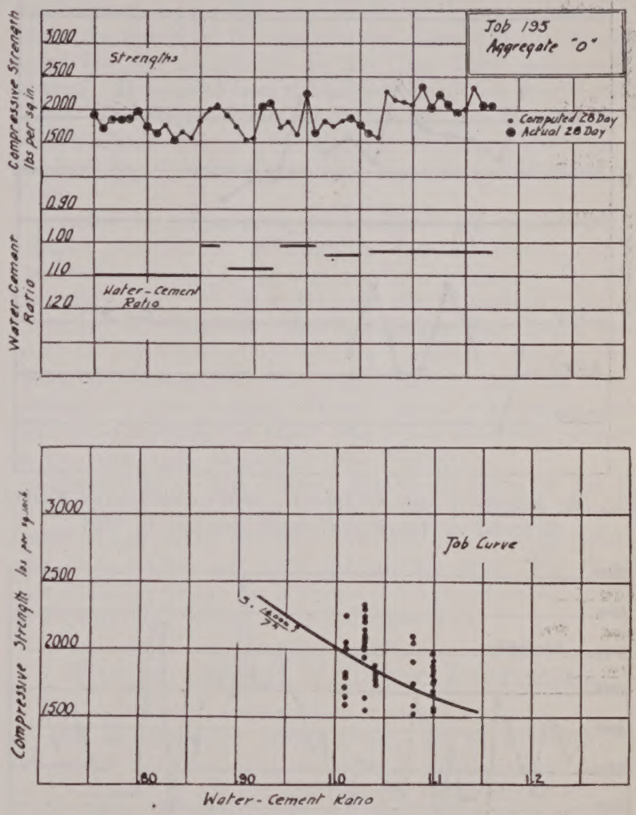


Fig. 9.—Job 195

We should look for a moment at the curves that were plotted from job tests made in 1923 under the old system of controlling concrete, and note the variation in strength, ranging from 1,500 lbs. to above 3,000 lbs. We should also note the line of strengths plotted directly from Table 4 of a paper by McMillan & Walker on the control of concrete on the Portland Cement Association Building built in Chicago last year. This was controlled by the water-cement ratio, but there is no indication of a high degree of uniformity. This lack of uniformity is evidently caused by not carefully controlling the variables which we have discussed. Where these are not properly allowed for, we may expect to find an excessive strength and a consequent waste of cement and other material. It is entirely within the limits of expectation, however, to secure concrete that will vary in strength not much more than 100 lbs. either way from the strength required in any specification.

It is proper to state, too, that of any group of cylinders, if any exceptional cylinder runs low it is apt to be caused by an inherent fault in the cylinder itself and not the result of low strength in the concrete. For this purpose note the comparison of core borings and cylinders taken from the job (Table 4), inserted from a paper by Mattimore from *Engineering News-Record.* This table shows the higher strengths that are obtained in the concrete in the structure than in the concrete cylinders both for averages and maximums. Therefore the rule that cylinders running more than 15 per cent below the average should be rejected and a new average computed, is a very safe one to follow; also it is to be noted there there is considerable safeguard in using the equation $S_{28} = S_7 + 30\sqrt{S_7}$.

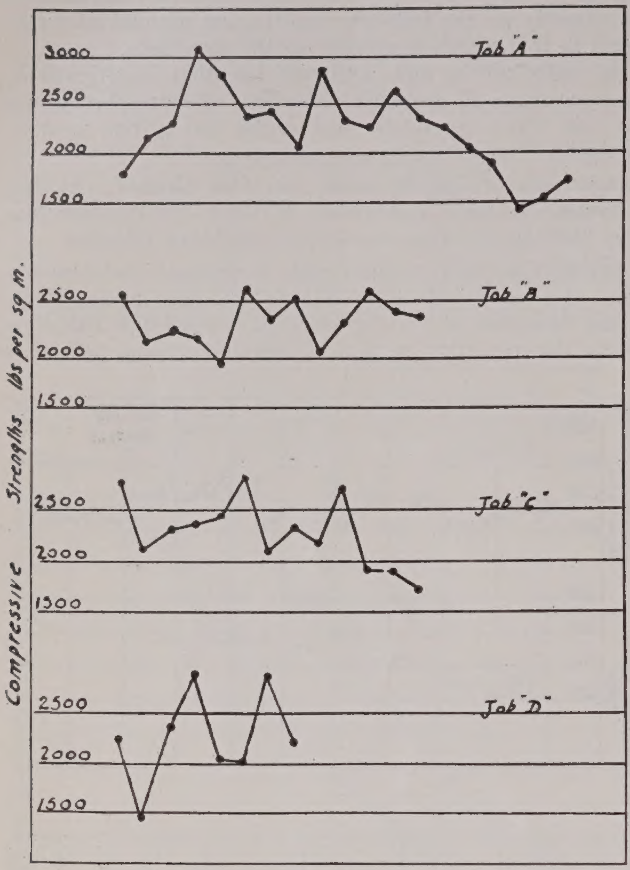


Fig. 10.—Results of tests by John G. Ahlers and Stanton Walker Reported to American Concrete Institute in 1923

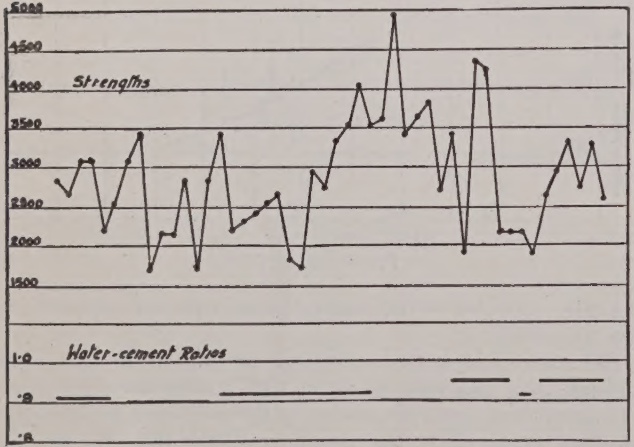


Fig. 11.—Tests on Portland Cement Association Bldg., Chicago Results taken from Table 4 of a paper by F. R. McMillan and Stanton Walker, presented before American Concrete Institute, Feb. 4, 1926

Table 4.—Comparison between core borings and molded specimens
Taken from article by H. S. Mattimore, Engineering News-Record, Jan. 12, 1922

	Molded Specimens at 28 Days	Computed Strength at 300 Days	Core Borings at 300 Days	Series No.
Minimum	2,211	3,320	3,980	2
Maximum	4,054	6,150	6,070	
Mean	3,095	4,680	4,545	
Minimum	2,115	3,200	3,860	3
Maximum	3,315	5,000	5,452	
Mean	2,788	4,220	4,706	
Minimum	2,229	3,370	4,185	4
Maximum	4,357	6,590	6,585	
Mean	3,368	5,100	5,288	

Strength as an Indication

There is much discussion of the fact that strength may not be the only indication of good concrete, and I believe there is also a good deal of confusion of ideas on this point. But Professor Abrams has shown conclusively in his tests that strength is indicative of all good qualities in concrete, as follows (Bulletin 17, "Studies of Bond between Concrete and Steel," Lewis Institute, page 10):

> The factors which produced high compressive strengths also produced high bond resistance. Other tests have shown that the same statement applies in general to resistance to wear, modulus of elasticity, impermeability and resistance to destructive agencies such as weather, sea and sulfate waters, etc. It is particularly striking that curves showing the relation between modulus of elasticity and compressive strength have a shape similar to Fig. 4. The significance of this intimate relation between bond and modulus of elasticity is not clear.

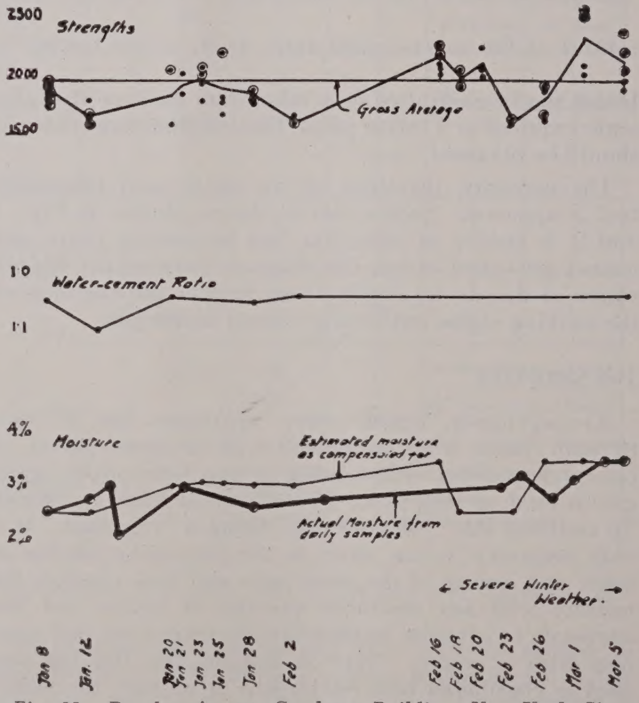


Fig. 12.—Results of tests, Goodyear Building, New York City

Furthermore, the Joint Committee on Concrete and Reinforced Concrete, in its proposed standard specification for concrete, bases all parts of design on factors of the ultimate strength in compression. This applies to bond, shear, modulus of elasticity, etc.

Data on Savings

On one of the jobs for which data are available (Lenox Laundry) there was an actual saving of $682.20 on 1,700 yds. of concrete. This is 40 cents a cubic yard actual saving, considering both aggregate and cement, and is no slight amount in any concrete job, no matter what its size.

On a larger scale job (a group of buildings aggregating 14,000 yds.) the actual saving in aggregate and cement amounted to $4,830. The total cost of test, including the services of two engineers, the breaking of cylinders, trucking, etc., was $2,700, leaving a *net* saving of $2,130, or almost 15 cents a cubic yard; the saving being about 35 cents and the cost of the test about 20 cents per cubic yard.

Conclusions

Finally, the statement that this method may not be 100 per cent perfect should be answered by saying, why wait until we have something 100 per cent? Supposing this method of control is only 95, 90 or 85 per cent perfect, it is better than anything we have had up to the present time, and it should be adopted and tried out by all who are aiming to make progress in securing better work and greater economy.

A special appeal is made to the engineers to give such a system of control as outlined a fair trial, and, in so far as possible, let the contractor use his own ideas and judgment as to the quantity, grading and proportioning of the aggregate. The engineer is urged to concentrate his attention on the factor that controls the strength, and that is the water-cement ratio. Let us adopt some system of absolute control of the ratio of water and cement entering into every batch and confine our efforts to watching this part of the production of concrete. It is not the only system, but it has produced excellent results and saved money, for owners as well as for contractors.

As an incentive to the contractors for the use of this system, let the engineer experiment on at least 100 to 200 yds. of concrete early in the structure so as to obtain an idea of what ratio will give the desired strength of concrete in the work. Co-operate with the engineer in every way possible, and learn something about it, for by actual learning and handling, the contractor will soon find that he is going to save considerable money on the work. He will be able to bid lower, strip forms with more safety, and he will feel more certain of the concrete in the structure and will have the satisfaction of doing a better and safer job.

Dense Concrete with Three Sizes of Aggregate

Concrete weighing 153 pounds per cubic foot is being obtained in the construction of the new city hall for Pasadena, California, through the use of three sizes of aggregates, the mixture running one part of cement to about two parts of sand, 1.1 parts of pea-gravel and 2.9 parts of coarse gravel. The grading factor of the combined aggregates averages about 5.4.

The sand and both grades of gravel are obtained from the San Gabriel river and are furnished by the Livingston Rock and Gravel Company. All the aggregates are washed.

The pea-gravel ranges in size from ¼-inch to ½-inch, and the coarse gravel from ½-inch to 1¼ inches.

Careful field control of the quality of concrete is maintained on this work, under the supervision of H. W. Hincks, a Los Angeles structural engineer. The concrete going into the structure is testing well above 3,000 lb. per sq. in. at the age of 28 days.

Try To Prevent Use of Cast Stone in New York

WASHINGTON, D. C.—Indictment of five trades union officials on charges of conspiracy to violate the Sherman anti-trust act by attempting to prevent the use in building in the New York district of cast stone manufactured elsewhere is announced by the Department of Justice. Five companies are mentioned as among the concerns against which the discrimination had worked. The work in the manufacturing plants within the New York district is done principally by members of the Machine Stone Workers, Rubbers and Helpers Association. The trimming of the stone and its installation in building are done principally by members of the Journeymen's Stone Cutters Association.

The indictments were returned July 7. The principal defendant is Michael W. Mitchell, international president of the Journeymen's Stone Cutters' Association. The other men named in the bill are Joseph Wall, a member of the executive board of the association; John Cronin, business agent for the association in the New York metropolitan district; Thomas O'Leary, business agent for the Machine Stone Workers, Rubbers and Helpers Association in the New York district; and William J. McGarry, president of the Building Trades Council of Westchester County, New York.

Among the manufacturers discriminated against by the alleged conspiracy, according to the indictment, are the Decorative Stone Company and the Economy Concrete Company, both of New Haven; the Onondaga Litholite Company of Syracuse; the Romberger Cast Stone Company of Allentown, Pa.; and the Lexington Stone Corporation of Baltimore. The conspiracy charged is one to prevent the Journeymen's Stone Cutters Association members from working on stone which has not been prepared by the New York Machine Stone Workers.

Complaints of the alleged agreement came to the Department of Justice after workmen are alleged to have refused to install in the New Rochelle N. Y., high school, cast stone which had been manufactured in New Haven. The building of the high school was considerably delayed as a result, according to the indictment.

Construction Volume Increases

The volume of construction operations under way increased sensationally during June. In no previous year on record have building activities reached so high a peak at this period of the summer season, according to statistics compiled by the Associated General Contractors of America. A 25 per cent increase over the May volume was registered. The total volume for the first six months of this year is 4 per cent greater than the corresponding figure for 1925.

The sudden increase during the past three months appears to be more than simply a seasonal spurt. The same forces that carried construction operations into record-breaking figures last year apparently are continuing to exercise themselves, according to experts here. It is pointed out that no previous year has seen the volume of building activities increase so greatly within three months.

If even the slightest increase over the June figure is made in July, a new record for construction activities within a single month will be established.

One of the most important topics now before the construction industry is that of the building code situation. We are on the threshold of a period of code revision and unification. The concretor will find it to his future advantage to see to it that his own requirements are taken care of in the new ordinances. A series of constructive articles on this subject will be published in succeeding issues.—The Editors.

Reinforced Concrete Predominate in Tall

Hotel Coronado Addition, 15 stories high

CONSIDERABLY more than 50 per cent of the large buildings constructed in St. Louis since 1917 have reinforced concrete structural frames. Two of these structures are 18 stories high, while no less than 11 buildings have a height of 15 stories or more. However, a reinforced concrete building considerably higher than anything thus far built in St. Louis is now contemplated. It may prove to be the tallest reinforced concrete building in the United States.

Four tall reinforced concrete buildings are now under construction in St. Louis, and three more have been turned over to their owners since January, 1926.

Architects and structural engineers formerly had an idea that 12 stories was about the limit of economy for buildings with reinforced concrete structural frames. This belief had taken deep root, in a manner similar to erroneous impressions that find lodgment in every new line of activity. The statement was accepted because of its frequent repetition. It is probable that prior to the war not one architect or structural engineer in a hundred who made the statement or acted upon it actually had investigated the matter for himself.

The general use of reinforced concrete structural frames for tall buildings in St. Louis is due in large part to the practicing structural engineers in that city, for they were among the first to question the old belief and to investigate and prove the utility of the reinforced concrete structural

City Club of St. Louis, 16 stories high

Missouri Building, 12 stories high

Structural Frames Buildings in St. Louis

frame for buildings of greater height than was commonly attained before the war. The Arcade Building, the structural frame of which was designed by F. C. Taxis, was one of the first results of those investigations. That structure, with a height of 16 stories above the sidewalk level and two stories below, was completed in 1918. It was soon followed by others of still greater height, both in St. Louis and elsewhere.

The availability of reinforced concrete in the construction of tall buildings received a further impetus in 1921 as a result of an elaborate series of fire and water tests completed by the Underwriters' Laboratories. The purpose of the tests was that of determining the fire-resistive value of various materials used in building columns. The full-sized test specimens were subjected to the sudden cooling effect of fire-hose streams while still in a highly heated condition. Much publicity was given to the results of the underwriters' tests following their completion. It will be sufficient to state here that reinforced concrete columns proved by far the most effective type in resisting the effects of fire and water, and this in turn strengthened the confidence of designers in the concrete structural frame.

Among the tall buildings in St. Louis having reinforced concrete structural frames those in the accompanying list are some of the most notable.

Mayfair Hotel, 18 stories high, at Eighth and St. Charles Sts. P. J. Bradshaw was the architect and Brussel & Viterbo were the

Shell Building, 12 stories high

Mayfair Hotel, 18 stories high

Melbourne Hotel, 18 stories high

structural engineers. This building is founded on concrete footings that cover nearly the entire lot area.

Landreth Office Building, 18 stories high, at Fourth and Locust Sts., completed in 1925. P. J. Bradshaw was the architect and Brussel & Viterbo were the structural engineers. This structure is also founded on spread footings, covering nearly the entire lot area.

Ambassador Theater and Office Building, 17 stories high, now under construction by the Boaz-Kiel Construction Co. The architects are C. W. & G. L. Rapp and the structural engineers are Lieberman & Hein.

Arcade Building, at Eighth and Olive Sts., 16 stories high, completed in 1918. The architect was T. P. Barnett and the structural engineer was F. C. Taxis.

City Club of St. Louis, 16 stories high, completed in 1924, at Locust and Tenth Sts. The architect was T. P. Barnett and the structural engineer was F. C. Taxis.

Addition to Hotel Coronado, 15 stories high, built in 1925. The older part of this structure, completed four years ago, has a reinforced concrete structural frame 10 stories high. The architect was P. J. Bradshaw and the structural engineer was W. J. Knight & Co.

Hampton Hall Apartments, Newstead and McPherson Sts., 15 stories high, completed nearly in 1926. The architect is Geo. D. Barnett and the structural engineer is W. J. Knight & Co.

Greystone Apartments, at Newstead and McPherson Sts., 15 stories high, near completion. This is a companion to the Hampton Hall Apartments, both of which were designed by the same architect and structural engineer and both were financed by G. L. Miller & Co. of New York City.

Melbourne Hotel, 3601 Lindell Blvd., 16 stories high, completed in 1922. The structural engineers were Brussel & Viterbo.

The Senate, an apartment hotel at Union Blvd. and Pershing Ave., 15 stories high, with a central feature having two additional stories. Now under construction by the Boaz-Kiel Construction Co. The architect is P. J. Bradshaw and the structural engineers are Brussell & Viterbo.

The Congress, an apartment hotel, a twin building to The Senate, also 15 stories high, with a central feature of two additional stories. Both buildings were designed by the same architect and structural engineers.

Shell Building, at Fourteenth and Locust Sts., 12 stories high, completed early in 1926. This structure has a circular front. The structural designer was W. J. Knight & Co.

Rice-Stix Dry Goods Co. Warehouse, 408-418 North 11th St., 12 stories high, completed in 1921.

Missouri Building, at 626 North Grand Ave., 12 stories high, completed in 1923. F. C. Taxis was the structural engineer. The architects were Helfensteller, Hirsch & Watson.

Louderman Building, at 11th and Locust Sts., 12 stories high. Completed early in 1926. The structural engineers were Brussel & Viterbo. Architects, LaBeaume & Klein.

Scruggs-Vandervoort-Barney Department Store Annex, 12 stories high, built 10 or 12 years ago. The architect was H. F. Roach.

Claridge Hotel, at 18th and Locust Sts., 11 stories high, completed in 1919. Architects Barnett, Haynes & Barnett.

Gatesworth Hotel, 10 stories high, on Union Blvd., near Lindell Blvd. Built by the A. D. Gates Construction Co.

Hotel, at 4907 Maryland Ave., 10 stories high. Brussel & Viterbo were the structural engineers.

Y. M. C. A. Building, at Locust and 16th Sts., 10 stories high.

This list of tall reinforced concrete buildings, compiled during a hasty survey of the city, is not complete, but it demonstrates quite emphatically the truth of the claim that the structural engineers of that city have in recent years saved their clients hundreds of thousands of dollars.

The reputation which several firms of St. Louis engineers have gained through their successful design of tall reinforced concrete buildings is well illustrated from the fact that one firm now has on its boards the structural plans for two 18-story office buildings and one 18-story theater and hotel building, all located in other large cities.

Did you know that the secret of good stucco is much the same as the secret of good plaster? Metal lath is considered an essential for plaster base. By using the same methods, and utilizing a 1:3 portland cement stucco, run on tight for maximum density for the sake of waterproofness, a good stucco will result. An experienced plasterer can apply stucco on frame or concrete masonry that will indeed be permanent.

French Government Opens New Technical School

On June 1, 1926, the French government inaugurated the "Ecole de Metiers de la Maconnerie, de la Taille du Pierre et du Beton Arme" at 9 Rue Saint-Lambert, Paris. Day and evening classes will be instructed and given practical work in all branches of masonry, stone-cutting and concrete construction. These courses are open to all and there are no fees attached.

By means of this school and others of the same type to be established in other cities of France the French government hopes to build up a native group of workmen skilled in all branches of the building trades and thereby overcome the necessity of importing foreign laborers. The new school is equipped with laboratories and machinery for testing materials, drafting rooms, lecture and study rooms and outdoor space for practical building instruction and actual construction work. Dormitories are provided for the students at the exceedingly low rate of one franc—about three cents at the present rate of exchange—per day and meals are served for three francs fifty centimes—about twelve cents—each. In addition the students receive pay for work done on actual construction jobs.

Besides Monsieur Labbe, directeur of technical instruction, representatives of the French army, the city of Paris, the Department of the Seine, the ministry of commerce and various building trades organizations assisted in the ceremonies.

Semi-Annual Meeting of the Concrete Reinforcing Steel Institute

The semi-annual meeting of the Concrete Reinforcing Steel Institute will be held September 13, 14 and 15 at the French Lick Springs Hotel, French Lick, Indiana.

The directors will meet at 10 a. m. on Monday, September 13, and the members will convene at 2 p. m. on the same day. On Tuesday there will be morning and afternoon sessions, culminating in the annual banquet of the institute. A final session will be held on Wednesday morning and will be followed by a golf tournament Wednesday afternoon.

Study Aggregate Grading

Washington, D. C.—A comprehensive study of the proportioning and grading of aggregates used in making concrete is being conducted by the Ceramic Division of the Bureau of Standards. The variables being considered are three different types of cement, the graduation of the coarse aggregate, and the ratio of the fine to the coarse aggregate when the latter is deficient in certain sizes. Aggregates from three different sources are being used; gravel, crushed stone and crushed slag.

As a result of the studies made thus far, it appears safe to follow in concrete design the criterion that the sand should be at least one-third of the total aggregate and that the graduation of the coarse aggregate should be such that the percentage passing any one sieve and retained on the next smaller should not be less than one-third that retained on the former sieve and passing the next larger one.

Do you sign your own work? Every artist is expected to do so. If you are an artist at making good concrete at a reasonable cost, there is no reason why you should not let your masterpieces carry your own private mark. Let the jobs carry your advertising long after the job sign has come down.

Corrosion of Structural Steel Within Concrete

A Discussion of the Effects of Corrosion and an Analysis of the Causes

By **GEORGE W. BURKE** and **P. B. PLACE**

IN a large dairy building a cheese room was located on the second floor. The apparatus discharged its waste onto the floor from where it was conveyed by means of a drain in the middle of the room to the sewer. After several years the mortar surface of the concrete floor had been attacked sufficiently to allow the waste material containing considerable organic matter and some weak acid to penetrate to the lower concrete, through which it diffused, thereby coming in contact with the reinforcing and structural steel. As a result the steel was badly corroded which caused it to occupy more space. By so doing the concrete was forced from the ceiling of the room below in large pieces and large and dangerous cracks were made in the ceiling beams.

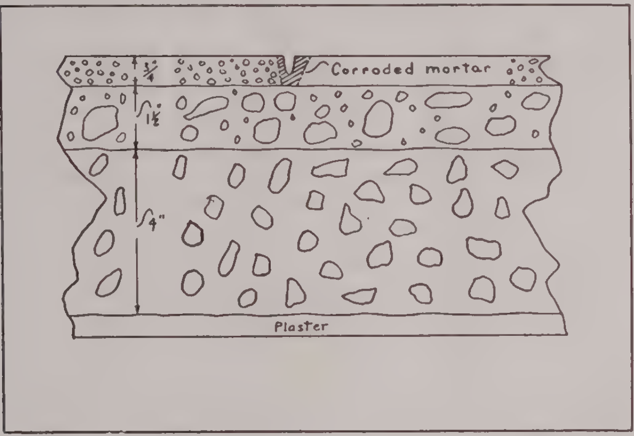


Fig. 1—Showing the make-up of the floor

It is only too evident that, due to the relatively great quantities of water used in dairy work, floors of concrete should be especially well built to avoid ill effects due to percolation of wash water containing much organic matter and in many cases dilute acids, probably most common of which are lactic and in some cases sulphuric from testing determinations. These acids both attack cement.

In the case under consideration the cheese making apparatus was located on the second floor of the building. The liquid that drained from the cheese ran onto the floor and eventually down a drain in the middle of the room. Due to improper drainage there were some places where the waste did not run away and consequently it stood in small pools and ultimately found its way into the concrete below the surface mortar.

Construction of Floor

The floor was built in three distinct layers as shown in Fig. 1. The surface coating was of mortar about ¾ inch thick, under this there was a layer of concrete about 1½ inches thick made up with a gravel aggregate, the largest of which was about 1½ inches. The bottom layer was about 4 inches thick and had a limestone aggregate about 1 inch in size. This was reinforced with steel. The surface coating was marked off in squares about 2 feet in size, the marking grooves being about ½ inch deep.

In parts of the room where the drainage was poor it seems that water was constantly standing in the marking grooves. Corrosion of the cement proceeded in such places and eventually the grooves became enlarged to such an extent that the liquid waste material gained direct access to the less dense and more porous concrete below.

	Surface mortar	Inner layer of concrete	Bottom layer of concrete
*Absorption by weight	4.0%	12.1%	12.0%
*Absorption by volume	9.2%	25.3%	24.9%
Specific gravity	2.3	2.1	2.1
Alkalinity (parts per million as $CaCO_3$)	——	170	720

*Boiling 5 hours. Same results were obtained with cold water under reduced pressure.

Table 1—Some characteristics of the concrete

These data demonstrate that the concrete beneath the surface was quite porous, no doubt due to excessive quantities of mixing water. Such being the case, water after finding its way through the surface coating had little difficulty in penetrating through the concrete to the reinforcing and structural steel.

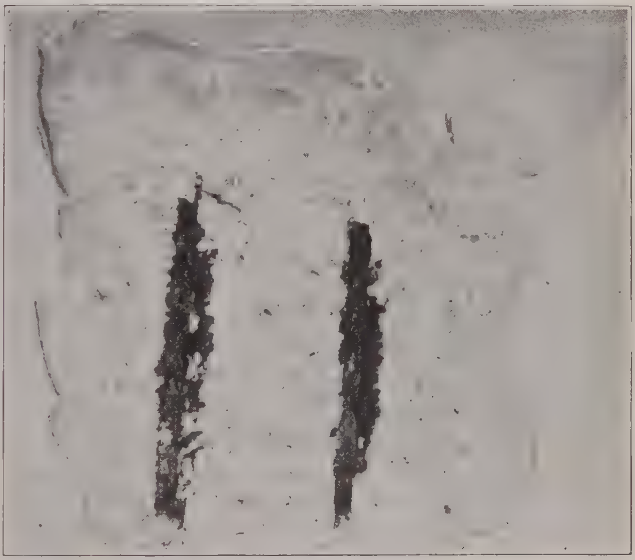


Fig. 2—Patches of the ceiling were pushed off by forces set up by expansion due to corrosion

Baylis[1] has pointed out that the alkalinity of crushed concrete is a fair and more or less indirect method of demonstrating its relative porosity which has made possible the entrance of carbon dioxide that has carbonated the caustic lime set free by water. It is apparent that such has been the case, especially with the concrete of the inner layer. In this connection I will add that under the conditions of this particular case it was probably true that considerable carbon dioxide came from decomposition of organic matter present in the water that penetrated into the concrete. The values for alkalinity were obtained on samples selected not in the immediate vicinity of the corroded steel. No doubt but what much lower values would have been obtained from samples adjacent to the damaged steel.

---

[1] Baylis, J. R. Corrosion of Concrete, Proc. Am. Soc. Civil Engr., Apr., 1926.

Effects of Rusting

The rusting of steel or iron proceeds with considerable expansion, and as the space for such increases in volume was not available, the forces became so great that necessary room was provided by cracking and pushing off the concrete. Fig. 2 shows very plainly how the pushing had proceeded to such an extent that the concrete was pushed off where the corrosion was greatest. Fig. 3 shows that corrosion of the structural steel had progressed so far that the concrete beam was severely damaged, making it necessary to shove it up from below. The laminated structure of the rust is clearly visible, demonstrating how much extra space was necessary for the steel under its present condition. It was possible to remove pieces of rust layers ⅜ inch in thickness. The forces produced by the addition of this extra material are quite sufficient to cause considerable damage.

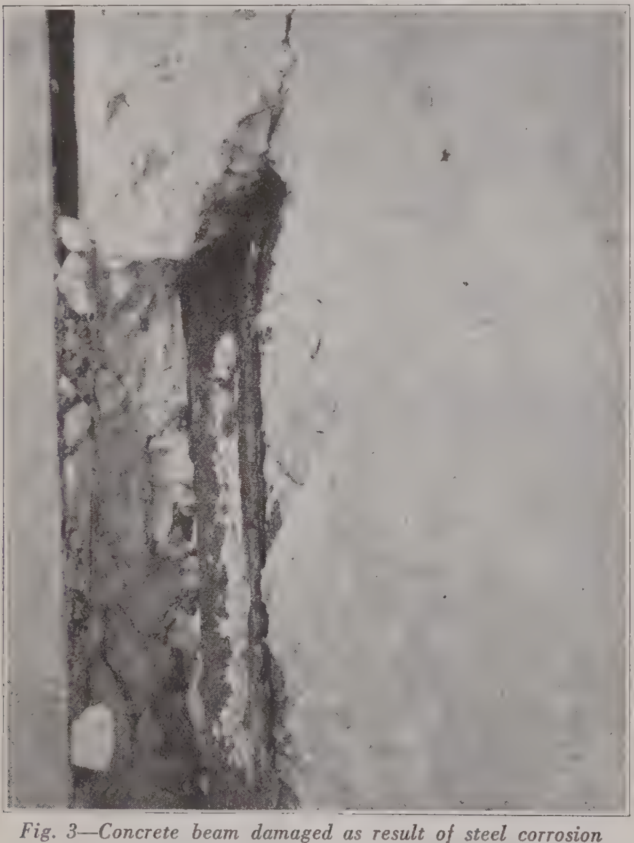


Fig. 3—Concrete beam damaged as result of steel corrosion

To avoid such difficulties it is therefore suggested that concrete which is to be continuously exposed to moisture and large quantities of water be so designed that water cannot penetrate to and come in contact with the reinforcing and structural steel. In the case of floors, proper and adequate drainage would be a decided advantage. It would also be advantageous to waterproof floors that are to be exposed to much water.

Arch Dam Research

The performance of concrete in the arch type of dam construction will be tested on the experimental arch dam now being built on Stevenson Creek, Fresno County, Calif. The Bureau of Standards is cooperating with the arch dam research committee of the Engineering Foundation in obtaining the test data.

Studies made in the preparation of designs demonstrate that very little is now known about the physical action of arch dams. Many elaborate theories of stress distribution have been proposed, but none has been found entirely logical or complete.

The theories thus far advanced are based upon limited knowledge of bridge arches where the action is much simpler than in an arch dam. In many dam locations the use of the arch dam in place of the heavier gravity type offers the possibility of combining marked economy with greater safety.

The experimental dam, designed according to the combined arch and cantilever method of analysis, is being built in order to obtain exact information under working conditions concerning the stresses, movements, and changes of volume of thin arch dams, so that design procedure may be brought into accord with conditions as found on a full-sized structure.

The dam is first to be built 60 feet and tested, then increments 10 feet in height are to be added until a height of 100 feet is reached. The upstream face, which is vertical, has a radius of 100 feet. The thickness of the dam from the crest down to a point 30 feet above the base is to be 2 feet, and from this point the thickness will be increased by a gradual curved batter on the downstream face to a base thickness of 7½ feet.

Three main factors are to be measured: deflections, deformations and temperatures. To obtain true values at least two independent methods of measurement will be used. The deflection measurements will be made from five steel towers five feet square and extending to the full height of the dam, located on the downstream side, each protected from the wind and unequal temperature stresses. The towers will be located at the center and 20 and 40 feet to either side. At 5-foot vertical intervals Invar distance pieces will extend from each tower to the dam, whereby the variation in this distance or the deflection can be measured by electrical means at a central point remote from the structure. To check deflection measurements a special clinometer will be used to measure variations in deflection between reference points which are also spaced at 5-foot vertical intervals. A third deflection measurement will be made by the use of theodolites.

Deformation is to be measured by 150 carbon disk electric telemeters buried in the concrete of the structure. Their resistance, which will be read at a central station, will give an index of the strain in the concrete at the telemeter location. Strains will be measured also by a specially designed strain gauge on a number of octagonal figures on the downstream face of the dam, located generally at 10-foot distances horizontally and vertically. Corresponding measurements will be made on the upstream face of the dam above the water line.

Temperature measurements are to be made with a coil of wire which will provide an electrical index of the temperature at each telemeter location. To check these, direct readings of the temperature will be taken.

Special care will be used to secure uniformity of concrete both in regard to various sizes of aggregate used and to the uniformity of the ratio of water to cement, as well as to the time of mixing. In addition to specimens to be tested at 7 days, 28 days and at some longer period, specimens will be retained for test at the time of the actual failure of the dam.

EDITORIAL

Building Codes

The building codes of America, like Topsy, just grew. There was no ordered, systematic attempt to "train them in the way they should go." Formulated by piecemeal and added to from time to time as the spirit moved, they have become a hodge-podge of unrelated, contradictory and ambiguous provisions that are often unfair and extremely difficult to untangle and evaluate.

They were originally formulated, for the most part, when brick, stone and timber frame structures alone held the field and the provisions incorporated were primarily for these types of structures. From time to time more provisions were added in an attempt to meet new requirements as new types of construction were introduced, until many codes have become so involved as to defy interpretation. The newer types of construction are burdened with provisions that were written into the codes for the older types. They still remain a part of the requirements even though they are unjust and often impossible to follow. Some of the newer types of construction are unnecessarily penalized by irrelevant requirements to such an extent that they cannot compete with the older building materials for which the codes were originally written.

Nor do the various building codes agree. Requirements vary within wide limits depending often on the personal prejudices of those responsible for drawing up the codes. Take, for instance, the building code regulations affecting the use of concrete block and other units, as revealed by a study of the codes in a number of the most important American cities. While the American Concrete Institute specifications call for an ultimate compressive strength of 1,200 pounds in concrete building units, the Hoover code recommends but 700 pounds, Birmingham calls for 1,000 pounds, Denver 700 pounds, Louisville 1,500 pounds, Milwaukee 700 pounds, New York 750 pounds, Pittsburgh 900 pounds, Salt Lake City requires 10 times the working stress, Washington, D. C., demands 700 pounds and Kansas City is considering a strength of 800 pounds. There can be no real necessity for such a wide variation in requirements when all the units are to be used in much the same type of structure.

Similar lack of agreement is to be found in the codes under the heads of absorption, percentage of hollow space, minimum web thickness and minimum wall thickness. Allowable wall heights come in for their share of variation both in height and in the manner of stipulating limits. Out of 24 building codes examined, 18 require hollow units to be branded and six insist that the date of manufacture be stamped on the unit.

This question of building codes is one on which perhaps more than on any other one feature, the growth of the concrete products industry depends, and it is the determining factor in many cases of the possibility of using reinforced concrete in structures. Concretors have a definite responsibility in this matter, and they have some important related problems to solve. First, they themselves must be agreed upon the proper values of the fundamental requirements in a fair building code. Then they must work to get such codes adopted by the cities in which they operate. Building codes must be rewritten and unified so as to clear up all the points that now lead to confusion. The present work on the Pacific Coast, where a modern building code, fair to all types of construction, is being developed, is a step in the right direction. This code will be available to all coast cities and is easily applicable to all. Great benefit to the concrete construction industry would follow similar activity, carried out on a national basis.

Beauty in Concrete

Always, since man began to build, he used the best materials conveniently available. By adapting them to his use and by giving them frank treatment, he has produced structures of beauty and usefulness. The discovery and utilization of every new building material has developed its own type of architecture. The frame house of New England, the stone house of the Middle Atlantic states and the adobe house of the Southwest are examples.

Evidences point to a similar development in the use of concrete. Architects are beginning to appreciate the possibilities of concrete and slowly there is evolving a new architecture built around this newest construction material. Never before has there been a material that combined the structural and decorative possibilities sought by the architect in such abundant measure as concrete.

Structurally, concrete has long ago demonstrated its superiority. Buildings of concrete are strong, enduring and fire-safe. Progress in concrete design made it available for every type of structure.

The aesthetic possibilities of concrete are only now beginning to be appreciated. No other medium presents a possibility for a greater variety and beauty of treatments. A plastic material, it provides a medium of expression that is appreciated by designers and builders of vision.

It offers a challenge to the architect. The frank treatment of concrete as a structural and decorative medium has resulted in structures of outstanding merit. Those who have secured the finest results with concrete have used it as a distinct building material, sought for its own peculiar qualities. It was not merely a structural material to be covered over by some other surface, or to be used in imitation of some other material. For them, a frank, undisguised treatment of concrete carried the greatest possibility for beauty.

The Old Codes and the New Ones

Beginning a New Series on the Building Code Situation as Related to Reinforced Concrete and to Concrete Masonry Construction—How Our Codes Were Developed—Overcoming Resistance—Confusion Resulting from Piecemeal Effort—Present Code Provisions—The Work of Unification

With this issue a series of articles is instituted on the subject of building codes and their provisions relating to the use of various forms of concrete construction. A number of subjects will be presented in different installments, and the supporting data will be of a very interesting and significant nature. This opening page will sum up the development of codes in general and the resulting conditions, while succeeding issues will describe the present situation with regard to concrete masonry, reinforced concrete, and other types of work, while other issues will bring out the results of current unification work. These stories should prove of real value to the architect, the engineer, the concrete products manufacturer, and the builder. They are dedicated to the ideal of honest competition and equal opportunity.

As is well known to the engineer and architect who have followed code developments for some years, most codes are not only woefully inadequate to meet modern conditions, but worse, they are frequently so involved and contradictory in their various provisions as to almost defy interpretation. There is a natural cause for this condition, for the very method by which the codes grew from their very beginnings could not be expected to result in the most beneficial situation. A study of the matter will show that the first codes took nothing into account but frame construction and masonry of brick and stone. For that matter no other types of construction were then known or accepted. Since there was but little reason to believe, at that period of our country's growth, that other and more economical construction ideas would be advanced, but little attention was given, in the original codes, to allow for such developments.

Then along came cast iron, with its high compressive strength, and its suitability to the construction of higher buildings. In spite of the unwieldy mass of such construction and in spite of the fact that it was but ill adapted to true fire safety unless protected by masonry, this construction flourished for a time under the beneficent condescension of the codes of the larger cities. Provision for this type of construction was mostly made by fragmentary amendments to existing codes, without thought to conflicting provisions already in the older portions of the codes.

Then came further improvement of material, structural steel. With the birth of structural steel came the birth of the skyscraper. In due time this type of construction was permitted by further amendments to the codes, without due regard to other provision that caused further confliction. A little later the necessity for fireproofing was realized, and further amendments were made to provide for that feature, using hollow clay tile or brickbats enclosed in lath and plaster. All this was not without a hot fight. Safety factors were made so high that masonry construction still retained the economic advantages for construction of the lower buildings.

The next advance was the introduction of reinforced concrete and the use of concrete for fireproofing the structural steel. Unfortunately there were a few who did not know just how to handle this new material, and occasional trouble was so magnified in the press that it was with the greatest difficulty that many codes were amended so as to permit the use of concrete. Again we find safety factors so increased and working stresses so decreased that reinforced concrete could not economically be used on the higher buildings. Further conflicting provisions again caused trouble. Structural steel still held sway, while brick and stone continued in wide use on the moderate-sized jobs, and the smaller homes, and even many of the larger ones continued to be built of frame.

Then along came precast concrete units. Here a very bad start was made, since the new industry attracted many who should never have been permitted to make concrete block. The result of this early period is too well known. Until almost the present time such construction was accordingly discouraged in the fire limits of many cities, regardless of the many good examples of concrete masonry already constructed. Then, too, the production of the hideous rock-faced block alienated the affections of the architect. It was not long, though, until a great housecleaning, aided and abetted by the automatic workings of economic forces, removed the greater part of the undesirable element from the field. A few short years of real preparation followed. Then came a rapid and healthy growth, until this infant industry has become an industry of real size and importance. The formation of an association, rigid rules of production, the issuance of certificates of quality to those producers who could earn them, all resulted in a material of high quality and fair price, and the public became interested. Still further code revisions followed, permitting the use of block and tile in many cities but adding still further to the confusion. Stringent code requirements again brought on high costs in many places.

Faced with this situation, and realizing the need for a new shuffle and deal of the cards, the Department of Commerce then sponsored a committee of experts whose mission it would be to study all present codes and formulate a model small house code and masonry code which would give sound minimum requirements that could be utilized by the communities of the country in rewriting the ordinances already in force. This work, belonging to the present period, is known to all. The report of the Hoover Committee has already proven invaluable. But still the work of code revision goes merrily along.

Few cities could agree on many points, as will later be shown, and there has resulted the situation that block which would be perfectly acceptable in one city could not be sold in another. One city would require one wall thickness and a neighboring community would permit another. Such a condition could do nothing else than localize the production of concrete units, in spite of the normal tendency of industry to broaden out.

In fact, the situation has proven so serious that the cities on the west coast have at last risen up in arms and are even now holding a series of conferences that are to result

(Concluded on page 31)

The Constitution of Portland Cement Clinker*

Part II of a Digest of the Literature on This Subject—The Researches and Theories of Henri Le Chatelier—Microscopic Studies — The Burning Process — Tornebohm's Studies — Comparison of Theories — Work of William Michaelis—Cobb's Experiments—Other Studies

By R. H. BOGUE

PART I of this series of articles on "The Constitution of Portland Cement Clinker," published in the July number of CONCRETE, discussed early views on this subject and described some of the first experiments made to find out just what portland cement really was.

Before portland cement as such was actually produced and recognized as a distinct material, various cementitious materials were made and attempts were made to develop a mortar that would harden under water. The ingredients of the various lime mortars then in use were analyzed in an attempt to produce better cements and scientists of note gave their time and energies to this subject. Smeaton, Higgins, Bergman, Vicat and others made careful studies and announced their theories, but as yet no definite principles were formulated and agreed upon.

Then came Joseph Aspdin who, by forcing the temperature of burning to high levels and controlling composition and grinding more carefully, produced a hydraulic cement "as hard as Portland stone." Aspdin patented his process and called the material he produced "portland cement."

In the years immediately following Aspdin's work, only a few engineers interested themselves in this new portland cement sufficiently to publish papers on experiments with this material. Such papers as were prepared were principally concerned with the methods and materials used in its manufacture and with the technique of its utilization, rather than with the underlying causes of why certain combinations of materials and manufacturing processes produced specific results. The views held by investigators up to this time were, for the most part, the product of speculation. Gradually, though, the use of cement brought about a desire to know more of the problems of what actually happened when portland cement was made.

The investigations discussed in Part I bring us to the time of Henri Le Chatelier who was the first investigator to enter into a thorough study of the chemical constitution of portland cement clinker. With the researches of Le Chatelier began the "Introduction of the Scientific Method" in research on portland cement clinker, which is the subject of Part II of this series.—*The Editors.*

Part II—Introduction of the Scientific Method

Henri Le Chatelier

Henri Le Chatelier[19] brought to the cement industry a hand of unusual experimental skill, a brain of marvelous perception, and a spirit of achievement which together have placed him at the front of all of his contemporaries, the nestor of scientific investigators on portland cement. It is a subject of marvel that, with the very limited means for measurements of precision which were available in 1887, Le Chatelier succeeded in discovering and postulating so many points which today are acknowledged to be facts.

The publications of Le Chatelier began to appear in 1883, but his work of greatest merit was embodied in his thesis published in 1887. This was translated and published in the United States in 1905.[19]

Synthetic Studies

In his earlier papers, Le Chatelier held that the orthosilicate, $SCaO.SiO_2$, was the chief if not the only hydraulic constituent of portland cement. Other compounds which he believed to be present were $3CaO.Al_2O_3$, occasionally with lime; $3CaO.2(Fe,Al)_2O_3$, a deep brown-colored alumina-ferrite of lime; and certain very small crystals, probably magnesium compounds.

The versatility of Le Chatelier is noted in the adoption by him, even in these earliest studies, of the polarizing microscope as the means for the identification of the crystalline phases in his clinker. His procedure included also the synthetic preparation of the compounds which he believed that he had identified in the clinker.

---

*Paper No. 3 of the Portland Cement Association Fellowship at the Bureau of Standards.

[19] Henri Le Chatelier, "Experimental Researches on the Constitution of Cements and the Theory of Setting." *Compt. rend.*, 94 (1882), 13; *J. Soc. Chem. Ind.*, *1* (1882), 151. "Experimental Researches on the Constitution of Hydraulic Mortars," translated by J. L. Mack, New York, 1905.

The orthosilicate, $2CaO.SiO_2$, was of especial interest to Le Chatelier because of the property it possessed of spontaneous disintegration, or *dusting*. He explained this as due to the presence of twinned crystals. The unequal contraction of the opposed faces of the twins during the cooling process he held to be responsible for the disintegration observed. This idea originated from a study of potassium sulfate which, at nascent redness, according to Mallard (*Cf.* Ref. 19, book by Le Chatelier, p. 53), shows:

> An extremely clear reversible dimorphic transformation which is accompanied by numerous twin formation. These twin crystals bring into contact different reticular planes the proximity of which determines the internal molecular tensions which are augmented during the cooling as a result of the inequality of the coefficients of expansion. It is conceivable that these tensions may bring about the disintegration of crystals having sufficiently easy cleavage.

Other materials exhibiting similar disintegrations are discussed by way of support to the theory given.

The disilicate, however, he reported later to be essentially nonhydraulic.

> After six months a sample of paste enclosed in a tube to protect it from carbonic acid crumbled immediately upon a simple pressure of the finger. However, I do not wish to say that at the end of a very long time water may not exert some action, because it is known that all the silicates, even the most acid ones, are slowly decomposed by water. These experiments nevertheless suffice to establish the fact that $2CaO.SiO_2$ can only take a secondary part, if any, in the hardening of cements.

Thus in this thesis he attributes to the disilicate a negligible role among the constituents of clinker.

Theory of Le Chatelier

Le Chatelier later believed in the existence of a tribasic silicate, $3CaO.SiO_2$, in clinker. This belief originated from the analysis of the grappiers, or nodules remaining on the hard burning of certain siliceous limestones. The ground grappiers were found to give a high quality of cement, and their analysis showed them to consist largely of lime and silica in the proportion to form $3CaO.SiO_2$. Hence, Le Chatelier believed that the essential hydraulic constituent of portland cement was also this tricalcium silicate. But all attempts to prepare it synthetically proved futile. On heating together lime and silica in the proper ratio, only a mixture of calcium silicates and free CaO were formed. The use of calcium chloride as a flux gave him the crystalline compound, $2CaO.SiO_2.CaCl_2$, but failed to effect the combination he desired. All further attempts to produce the trisilicate by fusion methods were unsuccessful, but he claims to have prepared it by decomposing the chlorisilicate with water vapor at a temperature above 450°C. He writes the reaction:

$$2CaO.SiO_2.CaCl_2+H_2O\ 3CaO.SiO_2+2HCl.$$

The reaction was incomplete, however, and the product could not be studied microscopically as it appeared amorphous, but it seems to have possessed properties of setting and hardening similar to those of cement. He found it to show no signs of swelling or cracking, which he regards as a certain indication of the presence of free lime, and adds,

> This characteristic, together with the property of setting which none of the lower silicates possess, shows clearly that we have to do with a compound and not a simple mixture whose properties would simply be the sum of those of the mixed bodies.

He regards these experiments as sufficient evidence for the existence of $3CaO.SiO_2$ in cement.

Tricalcium aluminate, $3CaO.Al_2O_3$, was prepared synthetically, and found to be the most fusible of the aluminates. More basic aluminates were not formed. Le Chatelier was unable to obtain calcium ferrites but, in the presence of alumina, double compounds were reported to be formed and considerably to augment the fusibility of the corresponding lime salts. The compound $3CaO.Al_2O_3.Fe_2O_3$ is described as a well crystallized salt consisting of long needles of a beautiful red color.

Microscopic Studies

Le Chatelier was perhaps the first to appreciate that chemical analysis revealed little concerning the nature of the compounds formed during fusion and crystallization. He was the first to apply the microscope consistently to this problem. He prepared thin sections of clinker and describes the following constituents:

1. Colorless crystals, with weak double refraction, with square or hexagonal cross sections and very clear borders much resembling those of the cube. It is by far the most abundant constituent.
2. In the space between these crystals, a ground mass, the color of which is always dark and varies from a yellow red to a greenish brown. Its double refraction is stronger than that of the preceding material, but it does not possess any clear crystalline contours.
3. Beside these two essential elements, accessory elements are frequently found, varying in different samples:
    a. Crystalline sections of forms and dimensions analogous to those first given, but which are distinguished from them by a light brownish, slightly yellowish color, a complete absence of transparency, and by very fine striae inclined to each other at about 60°. This constituent, although scarcely plentiful, is found, however, in almost all samples of cement of good quality.
    b. Very small crystals of sufficiently strong double refraction to give polarization colors. This constituent is always in small quantity and is sometimes entirely absent. It is found especially in underburned cements.
    c. Certain forms without action upon polarized light and of negative character which do not give any distinguishing test.

Since acids were found to attack all of the constituents of clinker, as viewed under the microscope, Le Chatelier concludes that "the essential elements of cements are therefore siliceous."

He finds the iron oxide to be present mainly in the flux surrounding the crystals, and magnetic oxide only as accidental inclusions arising generally from emery used in grinding. The alumina is not identified in any compounds, but is assumed to be combined with the iron oxide and lime. To summarize:

> The absence of free lime in portland cements of good quality is very certain; the existence of the aluminate is only probable.
>
> This chemical study of the calcined portland cements shows, therefore, that they are formed essentially of a calcium silicate differing little from the formula $3CaO.SiO_2$, which is the active element of hardening, and that the compound is produced of chemical precipitation in the midst of a molten double silicate, which has acted as a vehicle for the

> silica and lime to allow them to combine, but which remains sensibly neutral during their hardening.

The Burning Process

Le Chatelier describes the calcination or burning process somewhat as follows: The first reaction is the decomposition and dehydration of the clays at about 600° C. From 800° to 900° C. the limestone is decomposed to CaO and CO_2. At this time the clay begins to react with the lime, and the action becomes the more complete as the temperature rises and the time increases.

> At the points of contact of the grains of lime and the particles of clay, fusible products are formed which are diffused in opposite directions, becoming more basic on the one hand and more acid on the other. If we break up a nodule of clay, we will have in the center the elements of clay, infusible silica and alumina. Then the slightly calcareous fused glasses, afterwards a fused mixture of double silicates analagous to slags, with the mono- and dicalcium silicates, all fusible at the temperature of calcination of cements, lastly, the most basic salts, the active constituent of cement, infusible tricalcium silicate, and fusible calcium aluminates, and in the last place of all, quicklime. The proportion of these diverse elements varies in a continuous manner with the degree of advancement of the calcination, tending towards a limit dependent only upon the relative proportions of the elements present.
>
> With a large excess of lime, the final products will be quicklime, tricalcium silicate and tricalcium aluminate. By diminishing the quantity of lime, we would have these two salts and no quicklime. Afterward the calcium aluminate will disappear and will be replaced by a multiple silicate of a composition analagous to that of the basic slags from blast furnaces.
>
> This will be found in turn by the disappearance of tricalcium silicate, which will be replaced by dicalcium silicate with spontaneous pulverization; then by the monosilicate.
>
> Finally, glasses analagous to the acid slags of blast furnaces will be produced.

A. E. Tornebohm's Researches

The important researches of Tornebohm[20] were published ten years after the thesis of Le Chatelier, but without knowledge of this thesis. The points of especial interest in the papers of Tornebohm were (1) the designation of characteristic names for the several constituents of clinker as seen under the microscope, and (2) the separation of these constituents by means of liquids of high specific gravity.

Tornebohm identified four crystalline constituents, and an isotropic colorless glass which he found always or nearly always to be present in clinker. The crystalline substances he named: *alite, belite, celite* and *felite.*

The most abundant constituent he found to consist of colorless crystals of weak birefraction, rectangular or hexagonal. They showed a high index and biaxial interference figures. This he called *alite.*

Belite was designated by a greasy yellow color and bright interference colors. He states that the index it forms is small rounded grains with no definite crystal form, and that the grains are biaxial and often striated.

Celite, he stated, is easily recognized by its dark orange-yellow color and its strong birefraction. He reports that it is often present in the form of rods, especially in underburned clinker, while in well-burned clinker it forms the filling material and magma from which the alite separates.

Felite he describes as a colorless biaxial compound with strong birefraction. He reports that the index is high, being nearly the same as that of belite. The grains are usually rounded, sometimes elongated, and usually striated perpendicular to the elongation. It is found in variable quantity and often is entirely absent. It seems to replace belite.

The *isotropic residue* is described as a colorless amorphous material of an index as high or higher than that of alite. It constitutes a filling material which is not always easy to distinguish from alite.

A comparison of these compounds with those reported by Le Chatelier shows a passable agreement. The No. 1 of Le Chatelier appears to be the alite of Tornebohm. No. 2 corresponds with celite. No. 3a is similar to belite. No. 3b is probably the same as felite, and No. 3c seems to be the isotropic material of Tornebohm. The criteria for the identification of these constituents, however, are too inadequate to place great significance upon them.

Comparison of Researches

These conclusions of Le Chatelier and Tornebohm have constituted a foundation upon which have been erected many theories and hypotheses of structure, constitution and manufacturing technique.

But although Le Chatelier and Tornebohm find some agreement in their microscopic classification of cement constituents, they do not arrive at the same conclusions with respect to the chemical constitution of these substances. Le Chatelier regards the principal hydraulic constituent of cement as $3CaO.SiO_2$, which formula was arrived at through theoretical considerations, combined with studies on the composition of cement-like nodules obtained from the grappiers of hydraulic limes. Tornebohm on the other hand, believed alite to be a complex compound. He came to this conclusion by first making a separation of the alite from a cement consisting essentially of alite and celite. This he accomplished by making a fractional separation in heavy liquids, especially methylene iodide, but he admits that the separation was not complete, as some celite always remains with the alite. The product, essentially alite, then analyzed as follows:

	Per cent
SiO_2	20.33
Al_2O_3	7.19
Fe_2O_3	3.65
CaO	63.65
MgO	2.62
Na_2O	0.85
K_2O	1.04

By assuming that the product still contained 10 per cent of celite, he deduced the composition of alite as:

	Per cent
SiO_2	19.48
Al_2O_3	7.83
CaO	67.60
MgO	3.00
Na_2O	0.90
K_2O	1.19

By assuming, further, that the MgO and the alkalies play the same role as CaO, and substitute for it in equivalent proportions, the formula for alite was written:

$$9\ (3CaO.SiO_2)+9CaO.2Al_2O_3$$

Formulas for the other constituents of clinker were more difficult to express, and could not be established by chemical means. They appeared all to contain both CaO and SiO_2 with the possible exception of felite. Alumina could not be identified with certainty and was believed to be associated with the Fe_2O_3 in the colored flux.

The belite was reported to be present only in clinker somewhat low in CaO or high in SiO_2. Celite was stated to be a double silicate of alumina, iron and lime, but was thought not to have a definite composition. Tornebohm regarded it not as a chemical compound, but as a crystallized mother-liquor, separating after the other phases had appeared. The composition varied according to the conditions surrounding each clinker and the rapidity of cooling. Felite was observed only in imperfectly burned cements. It was thought to be easily decomposed and to consist probably of a calcium aluminate. In well burned and basic cements, the celite was believed to contain all of the alumina.

The isotropic material was thought to be a double silicate of CaO and Al_2O_3.

Wilhelm Michaelis

Michaelis[21] began his work on cements about 1867 but had little to report on the constitution of clinker until after Tornebohm had published his thesis. His views, however, were very different from those of Le Chatelier or of Tornebohm, and seem to be supported by less of experimental evidence but more of an introspective imagination and speculation based on his very extensive and intimate knowledge of the industry.

Michaelis believed that $3CaO.SiO_2$ did not exist in portland cement but, instead, that the hydraulic constituents were solid solutions of lime in less basic silicates and aluminates. This phase of the work of Michaelis will be discussed to better advantage in Chapter IV.

Next to alite in importance was celite. This reddish brown and poorly crystallized material he believed to consist essentially of dibasic compounds of lime. When the $2CaO.SiO_2$ present in celite dissolved $TCaO.Fe_2O_3$, the product became yellow or red.

He regarded belite as $3CaO.2Al_2O_3$, which had escaped being dissolved by the silicates. He arrived at this conclusion by observing that belite was birefracting, and since the only birefracting aluminate was the $3CaO.2Al_2O_3$, and since this compound appeared to be similar to belite, he regarded the two as identical.

The felite, according to Michaelis, was an inactive form of $2CaO.SiO_2$ and was undesirable in clinker. To prevent its formation the clinker should be quenched rapidly.

The MgO and Fe_2O_3 he believed to be combined in the ratio 2MgO or 2CaO to $1Fe_2O_3$. The tricalcium ferrite did not exist, he believed, and any excess CaO went into solution and caused unsoundness.

Michaelis believed there could be no overburning, but that by annealing at 900° to 1000° for some time the lime which had been dissolved by the silicates separated out again and so reduced the value of the cement by causing unsoundness.

Other Theories of the Period

During the period from 1895 to 1900 several investigators carried out experiments by which they arrived at the conclusion that free lime in rather large quantities is present in portland cement clinker. Most of these investigations were directed primarily at the solution of the phenomena of hydration, setting and hardening, and the conclusions respecting the constitution of the original clinker were more or less incidental.

Zulkowski[22] believed cement clinker to be a mixture of free CaO and a double silicate of lime and alumina of the formula: $4CaO.Al_2O_3.2SiO_2$. This ternary compound he called *hydraulite* and believed it to be the alite of Tornebohm, the chief hydraulic constituent of clinker. The method used by Zulkowski for determining the free CaO consisted in treatment of the cement with a dilute solution of hydrochloric acid.

Hart[23] reported as much as 30 per cent of free lime in cement clinker, obtained by extraction with a 10 per cent alcoholic solution of iodine. Hart believed that the lime liberated in this manner was the active agent of hardening.

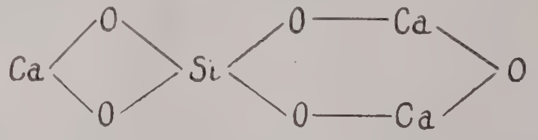
Other Studies

Wormser and Spanjer[24] reported large amounts of free CaO, obtained first, in alcoholic solution of aluminum chloride and, later, by a method using solid aluminum chloride and ammonium oxalate. Rebuffat[25] extracted CaO with sugar solutions. Many methods employing aqueous solutions have been used repeatedly, and these in spite of the admonitions by Michaelis that such reagents could not give exact results, and the report of Rohland[26] that quantitative proof of the existence or non-existence of free CaO or $Ca(OH)_2$ could not be obtained by purely chemical means.

Meyer[27] conducted a brilliant study as a result of which he concurred with Le Chatelier in the essential points on constitution. In 1901 he wrote:

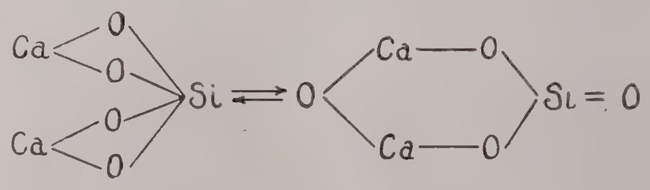
> In fact we have no evidence to prove the existence of free lime in anhydrous cement. On the contrary we may conclude by microscopic examination, or by observing the effect of the addition of a small quantity of strongly calcined lime, or by noting the effect when such lime is present due to underburning, that it is certainly impossible that free lime may be present in a portland cement of good quality.

Meyer accepted the hydraulic constituent of clinker to be $3CaO.SiO_2$ to which he assigned the formula:



He pointed out that this material would be hydraulic because it is an anhydride and so is capable of taking up water.

Meyer believed the dicalcium silicate to exist in two forms which were stated to be reversible at a high temperature:



Orthosilicate Metasilicate

The metasilicate he believed to be stable at high temperatures, that is, at the temperature of the kiln, while the orthosilicate was thought to be stable at lower temperatures. Thus he argued that, if a clinker is cooled slowly, the metasilicate will revert to the orthosilicate, and since the crystalline form under which the latter separates when first formed is unstable at ordinary temperatures, it dusts on cooling. This orthosilicate, he contends, is nonhydraulic due to the absence of an anhydride grouping. However, if the metasilicate is cooled rapidly by quenching in water, it remains as the metasilicate and Meyer believed is little crystallized but, rather, vitreous. Hence the quenching hydrates it but slightly. By grinding finely, the hydraulic properties become more and more active. The hydration here is due to the anhydride grouping.

---

[21] W. Michaelis, *J. prakt. Chem.*, (1867), 257. *Baumaterialienkunde, 11* (1906), 333; 352; 366; 381. *Protokoll Deutsche Portland Cement Fab., 32* (1909), 206. *J. Soc. Chem. Ind., 28* (1909), 836.

[22] Zulkowski, *Tonind. Ztg.* (1898), 318.

[23] Hart, *Tonind. Ztg.* (1900), 1676.

[24] Wormser and Spanjer, *Tonind. Ztg.* (1899), 1785; (1900), 1027.

[25] Rebuffat, *Gazz. Chem. Ital., 28* (1898); *Baumaterialienkunde, 4* (1899), 161; 205; 237.

[26] Rohland, *Tonind. Ztg.*, (1900), 1068.

[27] Meyer, *Bull. Soc. Sci.*, Bucarest, *9* No. 6 (1901); *Baumaterialienkunde, 6* (1901); 151; 159; 181; 212; 232; 248; 293; 309; 326; 347; 368; *7* (1902), 72; 111; 140; 156.

Meyer further argued that, when lime is present to the limit of saturation, only $3CaO.SiO_2$ and $3CaO.Al_2O_3$, or a highly basic iron alumina lime silicate, will be formed but, as the basicity decreases, the $3CaO.SiO_2$ decreases and double silicates of lime and alumina separate out. The rapidity of cooling, however, according to Meyer, determines whether the $2CaO.SiO_2$ will dust, as pointed out above.

Cobb's Experiments

An interesting series of experiments were carried out by J. W. Cobb[28] in 1910 on the reactions of some of the silicates and aluminates. Studies were made of the two, three and four component systems of CaO, Al_2O_3, SiO_2, and Na_2O, using as raw materials the oxides, carbonates or sulfates. Mixtures of various compositions were heated to various temperatures for various time periods and the extent of combination determined by finding the change in solubility of one or more of the constituents. Solubility was noted in hydrochloric acid and sodium carbonate solutions. Cobb found that reaction between CaO and SiO_2 began at about 800° C. With mixes high in SiO_2, the $CaO.SiO_2$ was believed to be formed, while with mixes high in CaO the $2CaO.SiO_2$ was produced.

Compounds of alumina were also believed to be formed the composition of which depended on the original composition of the mixture. Cobb believed these compounds to have the formulas: $CaO.2Al_2O_3$, $CaO.Al_2O_3$ and $2CaO.Al_2O_3$. A sodium silicate of the composition $Na_2O.4SiO_2$ and an aluminate of the composition $Na_2O.Al_2O_3$ were said to be made. In the mixtures of three and four components, the difficulties of calculating compound formation became very involved.

The many views on the constitution and the setting processes of cements which had been proposed up to 1903 have been discussed by Jordis and Kanter.[29] Apart from the excellent review and bibliography given by these authors, it is of especial interest to observe their own views, as occasionally expressed, which may be taken correctly to represent the state of the science at that time. Regarding constitution, they write:

> While some investigators believe it possible exactly to determine the compounds in clinker, others contend that this is not the case. Thus the conflict over the free lime in cement, which was kindled by Winkler and Feichtinger in 1856, is today not one step nearer to a solution.

And again:

> Our knowledge of the compounds formed by the burning of cement raw materials is very meager, and a great field for experimentation is open.

The following chapters show some of the means which have been used in the past two decades toward the solution of these problems.

---

[28] J. W. Cobb. *J. Soc. Chem. Ind.*, *29* (1910), 69; 250; 335; 399; 608; 799.

[29] E. Jordis and E. H. Kanter. *Z. angew. Chem.*, *16* (1903), 463; 485. Translated by E. W. Lazell, *Cement Age*, *1* (1904-5), 367; 450; 477.

Part III of this series, "The Development of Proportioning Formulas," will appear in the September number of CONCRETE

British Cement Manufacturer Overcomes Strike Difficulties

Some remarks of considerable interest were made by E. H. Murrant in the course of his address at the fifteenth annual meeting of the Ship Canal Portland Cement Manufacturers, Ltd. (of which he is chairman), which has just been held at Ellesmere Port, England.

At various times Mr. Murrant has referred to the great advantages the concern enjoys by reason of the location of its works at Ellesmere Port and the Manchester Ship Canal, which give it exceptional transport facilities. These advantages were never so clearly demonstrated as during the recent general strike. The strike caused a practically complete stoppage of almost all methods of transport, but notwithstanding these difficulties the concern's manufacture and deliveries during the first three months of the current financial year show an increase over the figures for the corresponding period of the previous year. The firm's plant, moreover, was not held up for a single instant during the strike. It was able to manufacture uninterruptedly by reason of having its own deep water wharf on the Manchester Ship Canal and direct access to the Shropshire Union Canal. Furthermore, when, recently, its coal stocks became depleted due to the coal strike, it was able to import coal direct to the works and thus be assured of continuing its plant in full production.

The company has entered into forward contracts at satisfactory prices, which fact, coupled with the regular daily flow of orders, ensures the disposal of the entire output for the current year. The position is such that an additional kiln is to be erected, which will not only increase the capacity of the works by 1,250 tons per week, but will reduce costs all round.

This concern operates the only important cement works in the Manchester area—an important industrial area with a population of over 10,000,000—and the works are the second largest in the country outside the associated combine.

"There is a much larger quantity of cement being brought into our local market than we ourselves are able to supply," declared Mr. Murrant, "and in view of the support which we have enjoyed from the local authorities and local contractors, there is every justification for increasing our production capacity in order to enable us to some extent to meet the continually increasing demands."

The Old Codes and the New Ones

(Continued from page 26)

in a uniform code for the adoption of all those cities where such revision would prove of benefit. This work should have its repercussions throughout the rest of the nation, for with such work accomplished in the coastal states the inland empire and the Atlantic seaboard would naturally also see its advantages.

It is this situation and this tendency toward needed unification that will be described in detail in later issues. The code requirements of many cities are being tabulated and studied. A store of data will be presented in the series that will prove of aid in further work.

Relation of Surface Area to Fineness Modulus

Discussion of These Two Methods of Determining Proportions—Explanation of Surface Area Theory—Mathematical Theory—Experimental Test of Theory—Tables—Practical Applications

By **M. O. FULLER**
Associate Professor of Civil Engineering, Lehigh University
AND
J. B. REYNOLDS
Associate Professor of Mathematics, Lehigh University

> Now, when questions of scientific design of concrete mixtures are so much discussed, a presentation of the two methods most generally used and their relations to each other, is particularly timely. The authors have made a thorough study of both the fineness modulus theory and the surface area theory of scientific proportioning and in the following article they present the results of an investigation into the relations between the two.—The Editors.

TWO methods of determining the amount of cement to be used in concrete mixtures have engaged the serious attention of engineers. The one is based upon fineness modulus, the sum of the percentages in the sieve analysis of the aggregates divided by 100 when the sieve analysis is expressed as percentages coarser than the mesh of a standard set of Tyler sieves.[1] The other is based upon the surface area of the aggregates.[2] The two methods have no simple relation to each other but it is the purpose of this article to show that a close approximation to the surface area may be obtained from the factors entering into the determination of the fineness modulus.[3]

The surface area method appears to have a scientific basis. From the results obtained it is apparent that for sand, at least a good value of the surface area obtained by sieve analysis. It is known that the water-cement ratio determines the strength of concrete. If it is assumed that the amount of cement paste required is proportional to the surface area of the particles to be cemented together it follows that to maintain constant strength and hence a fixed water-cement ratio it is necessary to vary the cement as the surface area of the aggregates. Thus it is evident that a knowledge of surface area is a valuable means of estimating the quantity of aggregates of the different sizes to be used with cement pastes of different water ratios.

It is proposed to show by the mathematical theory how the total surface area per unit weight is related to the surface area of a chosen size per unit weight and the percentages of all sizes in the analysis of a sample of aggregates. This theory will be checked by experimental data and finally a formula for practical use requiring no counting of grains in the aggregates will be obtained.

Mathematical Theory

Let there be N particles (similar solids) in a pound of the material making up the aggregates; let S be the specific gravity of the material, A the area per pound and f the density. Then for one pound of volume V

$$1 = VS = VS\ 62.5$$

whence $V = 1/62.5\ S$ assuming water to weigh 62.5 pounds per cubic foot.

Let d be any dimension of the N similar solids in a pound; then

$$V = kd^3N$$

in which k is a constant having different values for different shaped similar solids. Also since surface area varies with the squares of like dimensions we may write

$$A = k^1d^2N$$

in which k^1 is a constant varying for different shaped solids. From these relations

$$\frac{V}{A} = \frac{k}{k^1} d \text{ or } d = \frac{k^1V}{kA}$$

and therefore

$$V = k\ \frac{k^{13}\ V^3}{k^3\ A^3} N$$

giving

$$A^3 = \frac{k^{13}}{k^2} V^2\mathrm{N} = \frac{k^{13}}{(62.5k)^2} \frac{N}{S^2}$$

whence

$$A = \Lambda\ (N/S^2)^{1/3} \qquad (1)$$

in which the constant $= k^1/(62.5k)^{2/3}$.

If the particles are considered as spheres and N is the number of particles per gram the formula becomes

$$A_s = 236.1\ (N/S^2)^{1/3} \qquad (2)$$

in which A_s is the area in square feet per 100 pounds of aggregates. This is the formula used in practice.

The corresponding formula of the particles are considered as cubes instead of spheres as

$$A_c = 292.9\ (N/S^2)^{1/3} \qquad (3)$$

For the particles considered as regular tetrahedrons the corresponding formula is

$$A_t = 351.8\ (N/S^2)^{1/3} \qquad (4)$$

---

[1] See Bulletin No. 1, Structural Materials Research Laboratory by D. A. Abrams.

[2] See Proceedings of the Amer. Soc. for Testing Materials, 1918, L. N. Edwards, and Engineering News-Record. Jan., 1920, R. B. Young.

[3] See Design of Concrete Mixtures by Maj. F. S. Besson in Concrete, Jan., 1923.

Suppose a sample of aggregates run through a set of Tyler sieves numbers 1½, ¾, ⅜, 4, 8, 14, 28, 48 and 100 is found to contain a percentage p_0 retained on sieve No. 1½, p_1 on sieve No. ¾, p_2 on sieve No. ⅜, p_4 on sieve No. 4, p_8 on sieve No. 8, p_{14} on sieve No. 14, p_{28} on sieve No. 28, p_{48} on sieve No. 48 and p_{100} on sieve No. 100; each percentage to be expressed as decimal part of 100. Let there be N_0 particles per gram retained on sieve No. 1½, N_1 on sieve No. ¾, etc., to N_{100} per gram retained on sieve No. 100.

Since the successive sieve sizes are in the ratio of 2 to 1, if the rate of increase in proportion of smaller sizes from sieve to sieve is taken constant $N_0 : N_1$ as $1^3 : 2^3$, etc. Therefore

$$N_1 = 8N_0 \quad N_2 = 8N_1 = 8^2N_0 \quad N_4 = 8^3N_0 \quad N_8 = 8^4N_0$$
$$N_{14} = 8^5N_0 \quad N_{28} = 8^6N_0 \quad N_{48} = 8^7N_0 \quad N_{100} = 8_8N_0$$

Or the series of values might be written in terms of any particular one of the N's. For example:

$$N_0 = N_8/8^2 \quad N_1 = N_8/8^3 \quad N_2 = N_8/8^2 \quad N_4 = N_8/8$$
$$N_8 = N_8 \quad N_{14} = 8N_8 \quad N_{28} = 8^2N_8 \quad N_{48} = 8^3N_8$$
$$N_{100} = 8^4N_0$$

Let A_8 be the surface area in square feet per 100 pounds of the size retained on sieve No. 8, A_0 the surface area per 100 pounds of the size retained on sieve No. 1½, etc., to A_{100} that for sieve No. 100. Then assuming S the same for all sizes.

$$A_8 = 236.1\ (N_8/S^2)^{1/3}$$
$$A_0 = 236.1\ (N_0/S^2)^{1/3} = 236.1\ (N_8/8^4S^2)^{1/3} = \frac{236.1}{16}\ (N_8/S^2)^{1/3} = A_8/16$$

In like manner

$$A_1 = A_8/8 \quad A_2 = A_8/4 \quad A_4 = A_8/2 \quad A_{14} = 2A_8 \quad A_{28} = 4A_8$$
$$A_{48} = 8A_8 \quad A_{100} = 16A_8$$

Letting A be the total surface area per 100 pounds of aggregates, it follows that

$$(5)\quad A = p_0A_0 + p_1A_1 + p_2A_2 + p_4A_4 + p_8A_8 + p_{14}A_{14} + p_{28}A_{28} + p_{48}A_{48} + p_{100}A_{100}$$

$$(6)\quad = A_8\left[\frac{p_0}{16} + \frac{p_1}{8} + \frac{p_2}{4} + \frac{p_4}{2} + p_8 + 2p_{14} + 4p_{14} + 4p_{28} + 8p_{48} + 16p_{100}\right] = A_8P$$

in which P is written for the expression in the brackets.

Use will be made of the expression (6) for A in the application, but for the purpose of comparison it can readily be put in terms of the factors which make up the fineness modulus f for the aggregates. Let f_0 be the component of f arising from the amount of the aggregates that would be retained on sieve No. 1½, f_1 from the amount that would be retained on sieve No. ¾, etc.; then

$$f = f_0 + f_1 + f_2 + f_4 + f_8 + f_{14} + f_{28} + f_{48} + f_{100}$$

Now

$$f_0 = p_0 \qquad f_1 = p_0 + p_1$$
$$f_4 = p_0 + p_1 + p_2 + p_4 \qquad f_8 = p_0 + p_1 + p_2 + p_4 + p_8$$
$$f_{28} = p_0 + \dots\dots + p_{28} \qquad f_{48} = p_0 + \dots\dots + p_{48}$$
$$f_2 = p_0 + p^1 + p_2$$
$$f_{14} = p_0 + p_1 + p_2 + p_4 + p_8 + p_{14}$$
$$f_{100} = p_0 + \dots\dots + p_{100}$$

From these equations

$$p_0 = f_0 \qquad p_1 = f_1 - f_0 \qquad p_2 = f_2 - f_1$$
$$p_4 = f_4 - f_2 \qquad p_8 = f_8 - f_4 \qquad p_{14} = f_{14} - f_8$$
$$p_{28} = f_{28} - f_{14} \qquad p_{48} = f_{48} - f_{28} \qquad p_{100} = f_{100} - f_{48}$$

These values in equation (6) give

$$(7)\quad A = A_8\left[16f_{100} - 8f_{48} - 4f_{28} - 2f_{14} - f_8 - \tfrac{1}{2}f_4 - \tfrac{1}{4}f_2 - \tfrac{1}{8}f_1 - {}^1/_{16}f_0\right]$$

In deriving formulae (6) and (7) A_8 has been taken as the reference size since for this size the number of particles N_8 per grain is easily counted and since in the case of sands it may be the largest size retained on the sieves. It should be noticed that in equation (7) $f_{100} \dots f_{48} \dots f_0$ are the fineness modulus factors of the particles retained on sieves Nos. 100, 48 . . . . . . 0, none being the fineness modulus factor for the aggregate as a whole.

Having counted the number of particles per gram retained on sieve No. 8, N_8 is known. Then A_8 is obtained from $A_8 = 236.1\ (N_8/S^2)^{1/3}$ and the values of p_0, p_1, p_2 . . . . . . p_{100} from screening through a set of Tyler sieves and weighing the amounts retained on each sieve.

Two assumptions not exactly true have been made: First, that the specific gravity S is the same for all sizes and, second, that the rate of increase in proportion of smaller sizes is constant from sieve to sieve. How nearly these assumptions are justified will come out in the sequel.

Experimental Test of the Theory

Two major samples A and B of Succasunna sand, two C and D of Kenville sand, and two E and F of Delaware River sand, were run through a standard set of Tyler sieves, each for three minutes with a Ro-tap Sieve Shaker. Each sample contained 1000 gms. This process resulted in percentages of the sands being retained on sieves No. 8 to No. 100 as shown by Table I. The amounts retained on coarser sieves were so small that they were negligible.

Sample	P_8	P_{14}	P_{28}	P_{48}	P_{100}
A	2.5	13.1	21.9	36.2	20.6
B	2.8	12.8	22.2	37.8	21.5
C	2.8	11.0	20.0	35.6	25.6
D	2.6	10.1	19.7	37.4	26.1
E	3.2	11.8	21.3	36.6	22.9
F	3.4	11.7	20.4	37.7	22.3

P_8, P_{14}, P_{28}, P_{48} and P_{100} are per cent on sieves 8, 14, 28, 48 and 100 respectively.

Table I—Per cent retained on Tyler sieves

From each percentage of each major sample retained on sieve No. 8 were weighed out three samples of one gram each, from each retained on sieve No. 14 three samples of 1 gm. each, from each on sieve No. 28 three samples of 0.1 gm. each, from each on sieve No. 48 three samples of 0.01 gm. each, and from each on sieve No. 100 three samples of 0.01 gm. each, making ninety samples in all.

The 0.01 gm. samples were weighed on fine chemical balances to insure the greatest accuracy. The number of grains in each sample were then carefully counted and the average of each three taken as the basis to compute the number of particles per gram for that size in each of the major samples. There resulted the following table (Table II) of values of the number of particles per gram to which is added a theoretical set of values fitting the requirements to the mathematical analysis.

Sample	N_8	N_{14}	N_{28}	N_{48}	N_{100}
A	29	206	1450	6400	47900
B	24	185	1390	10500	57500
C	25	174	1270	10900	54100
D	24	130	1357	12200	58500
E	20	164	1290	11300	54900
F	20	175	1373	11200	65800
Theoretical	22	176	1408	11264	90112

Table II—Number of particles retained on Tyler sieves

In Table III will be found the sieve sizes and finess modulus factors.

Since these samples of sand contained no appreciable percentages coarser than sieve No. 8 there are no values of A_0, A_1, A_2 and A_4.

Computation of Surface Area

From the data of Tables I to V and the formula (5) making use of formulae (2), (3) and (4) the surface area in square feet per hundred pounds was computed consider-

Tyler Sieve No.	Size of Sieve Opening, in.	Per cent of sample coarser than a given sieve						Fineness Modulus Factors
		A	B	C	D	E	F	
1½	1.49	0	0	0	0	0	0	$100f_0$
¾	.741	0	0	0	0	0	0	$100f_1$
⅜	.371	0	0	0	0	0	0	$100f_2$
4	.185	0.5	0	0.3	0.3	0.5	0.2	$100f_4$
8	.093	3.0	2.8	3.1	2.9	3.7	3.6	$100f_8$
14	.046	16.1	15.6	14.1	12.9	15.5	15.5	$100f_{14}$
28	.0232	38.0	37.8	34.1	32.7	36.8	35.3	$100f_{28}$
48	.0116	74.2	75.6	69.6	70.1	73.4	73.0	$100f_{48}$
100	.0058	94.8	97.1	95.3	96.2	96.3	95.3	$100f_{100}$
Fineness Mod. f		2.27	2.29	2.16	2.15	2.26	2.23	

Table III—Tyler sieve analysis—Fineness modulus—Factors

In Table IV is given the specific gravity S of each size for each sample.

Sample	No. 8	No. 14	No. 28	No. 48	No. 100
A	2.62	2.62	2.61	2.61	2.63
B	2.61	2.60	2.61	2.62	2.62
C	2.61	2.62	2.59	2.61	2.62
D	2.60	2.60	2.58	2.60	2.62
E	2.61	2.60	2.58	2.58	2.68
F	2.62	2.63	2.58	2.59	2.68

Table IV—Specific gravity of various sizes

	Area per 100 lbs				
Sample	A_8	A_{14}	A_{28}	A_{48}	A_{100}
A	382	734	1410	2310	4500
B	359	711	1390	2720	4796
C	364	693	1356	2761	4694
D	360	632	1389	2874	4823
E	338	683	1367	2817	4651
F	337	693	1395	2800	4941

Table V—Surface area in square feet per 100 lbs.

ing the particles as spheres, cubes and regular tetrahedrons respectively. The resulting values are given for each sample in the first three columns of Table VI. In the fourth column is found the value of the area in square feet per hundred pounds computed by the short method of formula (6) using the value of A_8 given by the formula

$$A_8 = 236.1\ (N_8/S^2)^{1/3}$$

	Surface Area per Hundred Pounds Formula (5)			
	Particles considered as			Formula (6)
Samples	Spheres	Cubes	Tetrahedrons	$A = PA_8$
A	2183	2701	3244	2807
B	2469	3063	3689	2743
C	2541	3152	3786	2912
D	2682	3327	4009	2948
E	2479	3074	3694	2628
F	2535	3149	3774	2586

Table VI—Variation of computed surface area by various methods

By comparing the fifth column of Table VI with the second, third and fourth, it is seen that the results obtained by the short method proposed in this article are in every case greater than those obtained by counting and considering the particles as spheres, and in every case but one less than those obtained by counting and considering the particles as cubes.

Since regarding the particles as spheres requires the least surface possible for the volume, it follows that the actual surface is greater than that found on this assumption. The results obtained by the short method of formulae (6) or (7) are therefore probably more nearly correct than those obtained by regarding the particles as spheres.

The reason for the discrepancy between the results found by formulae (5) and (6) is brought out by Table II where N_{100} for the theoretical series is 90112, while for the actual cases the average value for N_{100} is about 56500. This comes about because in the percentage retained on the No. 100 sieve there are many more particles in number of the larger sizes compared to the smaller sizes than is the case in the percentages retained on the other sieves. By Table II it is seen that a theoretical series

22 176 1408 11264 56320

would be a much nearer approximation on the average than the given theoretical series. This series would require

$$N_{14} = 8N_8 \quad N_{28} = 8^2N_8 \quad N_{48} = 8^3N_8 \quad N_{100} = 8^3 \times 5N_8$$

and therefore

$$A_{14} = 2A_8 \quad A_{28} = 4A_8 \quad A_{48} = 8A_8 \quad A_{100} = 8(5)^{1/3}A_8$$

and would result in the following formula for the approximate value A^1 of A

$$A^1 = A_8\ [p_8 + 2p_{14} + 4p_{28} + 8p_{48} + 14p_{100}]$$

Calling the bracket p^1 and computing A_8 for $N_8 = 176$ with the average value of S we may write as an approximate value

$$(8) \qquad A^1 = 350\ P^1$$

The values obtained for A and A^1 by using formula (6) and (8) are given in Table VII.

Surface Area	Sample					
	A	*B*	*C*	*D*	*E*	*F*
A	2183	2469	2541	2682	2479	2535
A^1	2430	2521	2618	2682	2543	2527
% Variation	11	2	3	0	3	0

Table VII—Variation in surface area as computed by formulas
A—Formula based on percentages and area on 8 sieve.
A^1—Formula 350 P^1.

The greatest variation of A^1 from A is in case of sample A and is about 11 per cent. It should be remarked that throughout the results of this sample are at such variance as to arouse suspicion. However no sufficient reason for disregarding it was known. The other variations are seen to be very small. Considering the nature of the work closer agreement would scarcely mean greater accuracy.

In conclusion this investigation shows that for sands at least the formula

$$A = 350 \left[\frac{p_0}{16} + \frac{p_1}{8} + \frac{p_2}{4} + \frac{p_4}{2} + p_8 + 2p_{14} + 4p_{28} + 8p_{48} + 14p_{100}\right]$$

$$(9) \qquad A = 350\ P^1$$

may be safely used to compute surface area in square feet per hundred pounds. In computing

$$P^1 = \frac{p_0}{16} + \frac{p_1}{8} + \frac{p_2}{4} + \frac{p_4}{2} + p_8 + 2p_{14} + 4p_{28} + 8p_{48} + 14p_{100}$$

p_0 is the percentage as a decimal of the sample retained on sieve No. 1½, p_1 the percentage retained on sieve No. ¾, etc., to p_{100} the percentage as a decimal retained on sieve No. 100.

Adapting a table given by R. B. Young in the *Engineering-News Record*, January, 1920, to our results, we form Table VIII for practical use.

Required Strength of Cement per sq. in.	Pounds of Cement per 100 lbs. of Aggregates	Water-Cement Ratio
2500 pounds	$11.13p^1$	.68- .74
2000	$9.03p^1$	.78- .86
1500	$7.28p^1$	.91-1.04
1000	$5.18p^1$	1.14-1.37

Table VIII

Serious losses are due to the practice of storing aggregates on the ground. The entire pile cannot be picked up again and run through the mixer, for a great deal of dirt would be included. Thus the extra charge for materials that must be added to the cost of the work is a clear loss. If overhead storage is out of the question, a temporary wooden platform comes in handy.

Demonstrating Good Concrete Masonry Construction

The Idea Behind the Lehigh Homes—The Type of Construction—The Plan of Campaign—What It Means to the Concretor—Pictures That Show the Work on Two of the Demonstration Homes

NOT only the entire cement industry, but the concrete products industry, the contractors, the architects, and the material men as well, are reaping a great deal of benefit from an unusual publicity campaign now being carried on by one cement manufacturer, the Lehigh Portland Cement Company. This campaign, centered around the construction of a number of concrete masonry homes, planned by leading architects, is calling the attention of the public to the merits of concrete masonry and portland cement stucco construction, and promises to bring more business to the products manufacturer, the contractor, the mason, the plasterer and the material man. The campaign will be of benefit to every concretor, since a great many people will be sold on the general idea of concrete construction and will do business with builders and products men specializing in concrete house construction.

As has already been mentioned in this journal, the houses being built by the Lehigh Portland Cement Company were selected from a great number of small house plans submitted as entries in a competition by architects all over the country. The prize homes are those selected for construction. These same plans, together with a great many others selected from the entries of the various architects, have been assembled in a book issued by the company, and this is receiving wide distribution. Local dealers are utilizing this book in several ways, one of which is to obtain plans for demonstration homes that they themselves are erecting.

The merchandising plan behind the entire scheme, which is naturally aimed at encouraging concrete house construction, is divided into two parts. The first is a national advertising campaign in general magazines and trade papes, based upon the booklet and the demonstration homes. This has for its purpose the securing of the names and addresses of good prospects. As fact as the names are secured they are entered on cards, and sent to the local dealers to whom the work of follow-up will be entrusted. The second part of the plan is for the dealers to build local demonstration homes, with or without aid, together with an advertising campaign in the local papers.

These advertisements all play up the architectural competition and the erection of the prize homes. They then tell about the house book and close with a coupon which may be used by any one desiring a copy of the book. A price of 10 cents is set upon the books in order to discourage curiosity seekers. As rapidly as these coupons are secured by the company a copy of the booklet is sent to the person sending in the request, and the coupons are then sent in to the local Lehigh dealer, who attends to the follow-up.

At the same time architects and contractors are being approached in order to get them to join in on the drive and to convince them of the merits claimed for that particular brand of cement.

Two separate booklets have been prepared, one for the material dealer and one for the products manufacturer. These books discuss the campaign and its application to the block plant or material yard, and tell some things about concrete masonry home building that may not be familiar to many in the field.

The architect is interested in the work on the basis that the company has no plans for sale to the general public. In fact, these plans are to be secured only through the local dealer. A local architect is usually expected to supervise the construction of the homes at the regular fee.

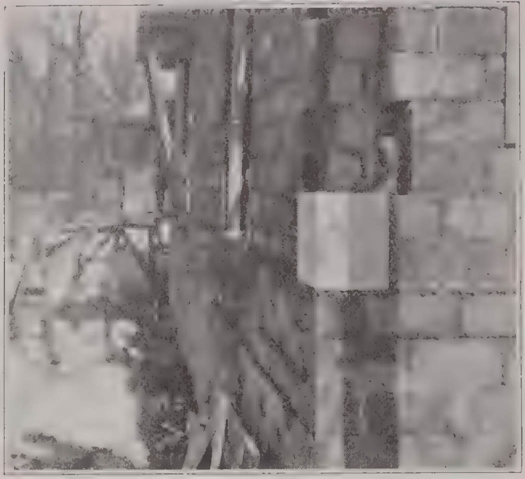
This work is of equal importance to the contractor and the products manufacturer. The mason contractor and the concrete contractor find that concrete masonry construction is growing in favor with the public and a great many contracts for the construction of homes shown in the Lehigh book after people have inspected the demonstration homes built by the company or by the local material dealer. The products man benefits because the demand for his block, brick, tile and trimstone increases as the campaign progresses.

As the demonstration homes are opened in the various cities the local newspapers are given advertising contracts covering a short campaign announcing the opening of the houses and attracting visitors to them. The same papers are requested to publish news items about the house, and for the most part the papers have shown considerable generosity in this respect. The result has been that a great many people visit the demonstration homes and their names are secured for the benefit of the local dealer and the local products manufacturer. The homes are completely furnished and are in charge of an experienced hostess, assisted by a considerable staff of Lehigh salesmen who act as guides. After the homes have been open for some weeks they are closed and disposed of through the local Realtors.

The homes show a variety of good concrete construction. In some the floors are of concrete, and in that way demonstrate a maximum degree of fire safety. Concrete masonry with portland cement stucco is a feature found in every one. The construction is of the very best and the design is of the most modern type in every detail. Taken altogether, the plan is so well worked out that it is a fine example of how a cement manufacturer can apply the principles of a high order of salesmanship and merchandising to indirectly increase his own sales.

On the following two pages is a group of pictures taken at two of the houses during the course of construction. The pictures are interesting as they show a number of worthwhile "kinks" and demonstrate the sturdy construction employed in the Lehigh houses.

Snapshots that Show the Work



Setting precast quoin in concrete block wall

Laying up flue lining in concrete masonry chimney

Forms for concrete floor slab and foundation walls being set

Concrete floor cast as a unit with foundation wall

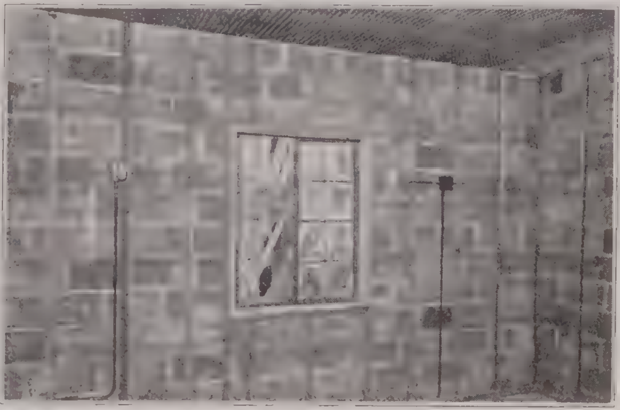
Setting reinforcing for the first floor slab shown above

# of Building the Lehigh Homes

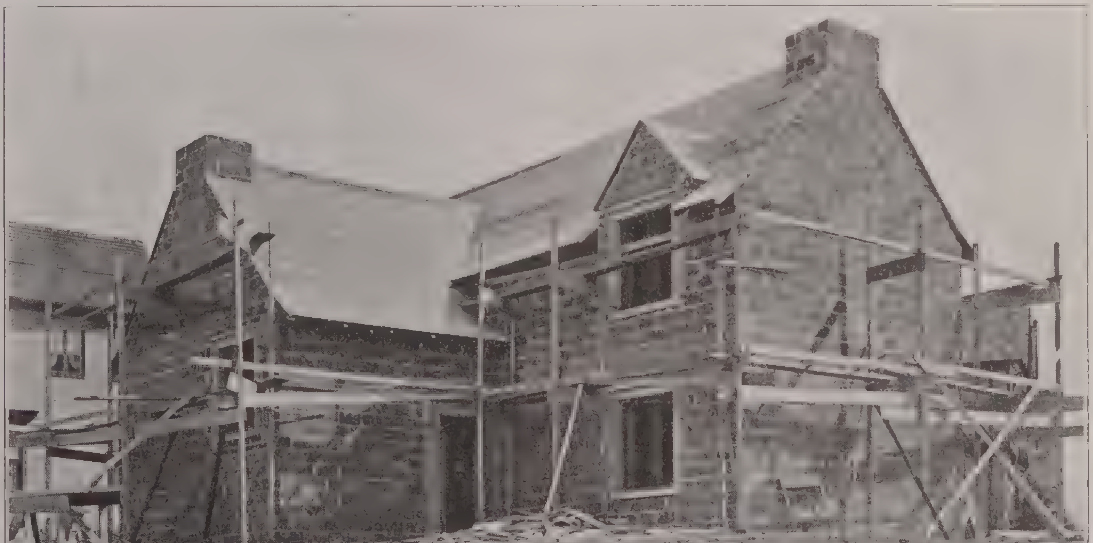
Kitchen door frame and precast trim in place, with wall angle going up

Setting precast door jamb for the main entrance to the Kansas City home

Applying the stucco on the concrete masonry wall



Metal lath furred out on concrete masonry wall ready to carry inside plaster

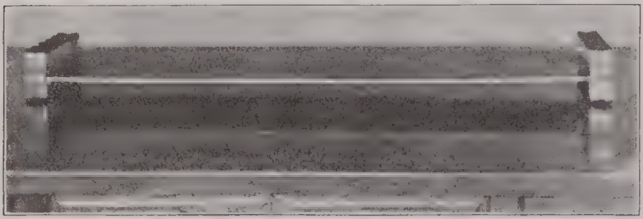


The Kansas City home under construction, with roof sheathing in place

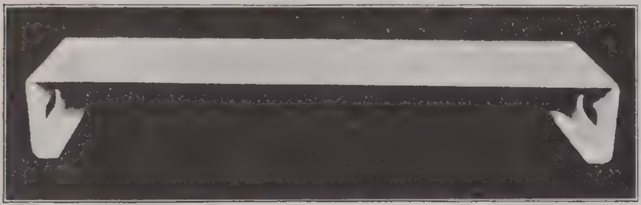
Some New Products Handling Equipment

New Types of Pallets That Have Been Developed to Facilitate the Handling of Products by the Various Methods

NOT so long ago the pressed steel pallet made its appearance in the concrete products industry and was first announced in our pages. So diversified have been the handling methods in the thousands of plants that it has become necessary to further extend pallet designs so as to better adapt them to the needs of the industry. Several new designs have now been brought out to meet the requirements, and these new pallets should prove of interest.



Brick pallet for use with Besser machine. It improves the tamping action and makes stacking an easy matter



The brick pallet designed for machines such as the Eberling, Anchor, Shope and others

One point of great interest is that the proponents of the pressed steel pallet have been negotiating with the makers of tile machinery and this work has resulted in a fair degree of standardization of concrete tile of the 5x8x12-in. tile. The size of pallet decided upon is 7⅝ in. by 11⅝ in., and makes a tile 7¾x11¾ in. A variety of core openings of standardized dimensions, together with standard thickness of webs, have been provided to satisfy the individual requirements of the various localities. The styles offered show a wide enough choice to satisfy the average tile maker. A special pallet has been devised for the Heskett machine, making two 5x8x12 tile at once and having a self-racking feature that is interesting.

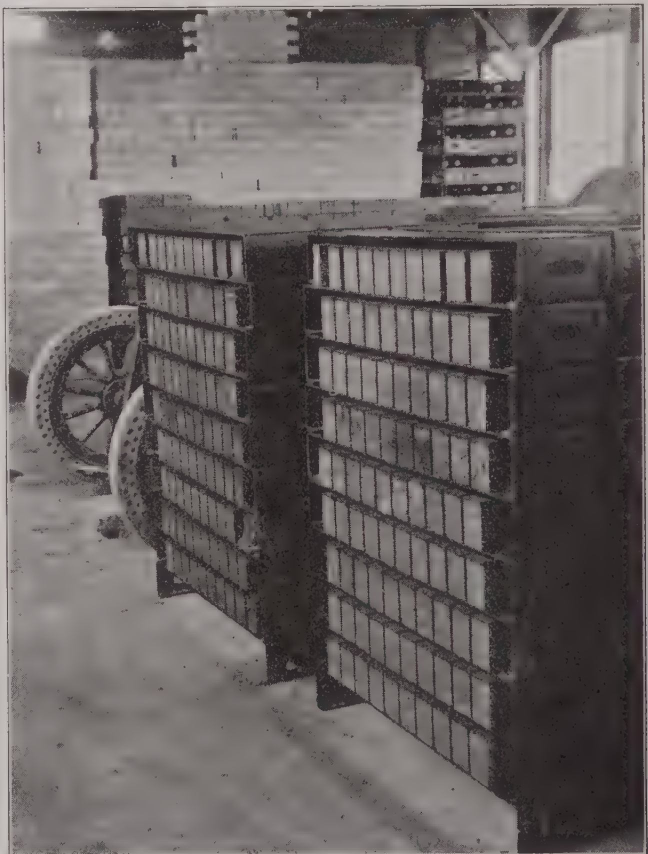
Another development of interest is the series of new concrete brick pallets that have been recently announced.

In the manufacture of concrete brick the very nature of the process of molding requires that the mix be rather dry as compared with poured concrete. The concrete must stand alone after it has been tamped, without support on the vertical surfaces. It is absolutely necessary that the supporting surface remain true and not be subject to any twisting, bending, or give in any direction as the result would be cracked or broken products. By the very nature of the molding operation, enough moisture cannot be introduced into the mix to overcome this cracking tendency.

Heretofore, wood has been used largely for the manufacture of concrete bricks. While wood has been relatively cheap, it is open to the objection that under the alternate steaming, cooling and drying, the wood warps and in a comparatively short time splits or cracks, rendering the pallet unfit for further use. Pallets used with cracks in them, leave an impression of the cracks on the bricks. Pallets used when warped and cracked, often produce cracked brick, due to the pallet springing back to its warped position after the pressure of the molding operation has been removed.

In certain instances a light sheet metal pallet has been used which has not the proper requisite stiffness from corner to corner to prevent the pallet from winding. When the pallet is lifted at both ends and twisted slightly with the brick on it, it is very likely that the whole load of bricks will be cracked through the center.

Two systems of handling are in general employment for curing concrete brick. The steam room, namely the rack



The Anchor pallets are stacked in tiers of ten, a total of a thousand bricks to the stack. No racks are needed. A two-wheeled truck like the one shown in the photograph is used to move stack

The tile pallet that makes two Heskett tile at once. It is self racking, just as are the brick pallets

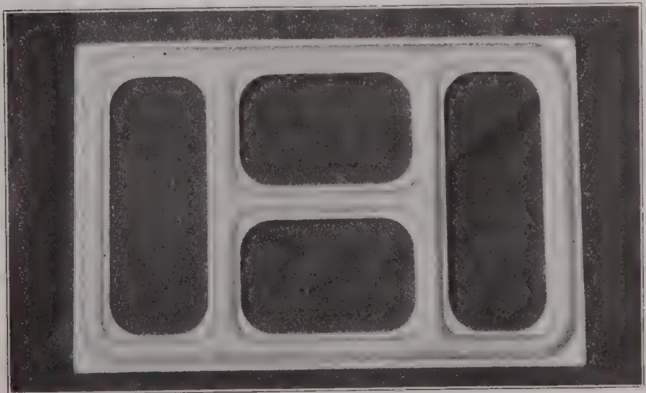
car system and the self-racking system. In the rack car system the pallets are flat and thin and are slid onto shelves in steel racks which are put on narrow gauge cars and rolled into the tunnels. Sometimes the racks are so constructed that a lift truck is used to haul the load racks into the steam room.

In the self-racking system the pallets are so designed that one pallet will rest on top of another and still provide space between for the brick. In this case a flat top car is sometimes employed. The pallets are racked up one on top of each other with the bricks between or they are racked up in single tiers under which a two-wheeled pronged truck is and wheeled into the steam room, where the stacks of eight or ten pallets each are set down. A new type of off-bearing equipment is also being promoted, in which the loaded pallets are discharged onto a wire rope conveyor and transferred from this to a transverse conveyor which goes to the steam tunnels. This type of equipment uses the self-racking type of pallets.

Probably one reason why the self-racking system in handling bricks to the steam room has not found more favor than it has up to the present time, has been due to the fact that it is very difficult to produce a wood pallet with sufficient strength for this purpose. If the bricks are made on edge, the wooden pallet will have to have a cleat at least 4½ or 5 in. high, whereas if the bricks are made on their face, a pallet is required with at least 3 in. of cleat on each end. These cleats, of course, have to be nailed onto the pallet and in handling and throwing around the cleats become loosened, the nails rust, and the pallets generally get out of shape so that when racked one on top of the other, the racks are very insecure and damage to the brick is liable to result. The life of the wooden pallet under these conditions is very short and replacement must be made at very frequent intervals.

There are now being designed and manufactured two types of self-racking pallets for use on brick machines which practically eliminate all of the difficulties aforementioned.

One pallet was especially designed for use in connection with the Besser machines, in which the bricks the face of the brick correspondingly true. The steel being are tamped on the pallet with the side down. This presents a smooth and true surface to the brick which makes only about 3/16 in. thick, there is about another 1½ in. drop to the tamper feet on the Besser machine, which produces a much harder and more firmly tamped brick of the same mix. Another factor that tends to produce a more firmly tamped brick is the elimination of the soft spongy action of the wood underneath the tamper feet. When the wood pallets have been split and warped they do not lie flat on the anvil and therefore there is a spring and a give under the tamper feet when they strike home. With the steel pallet the pallet lies firmly on the anvil and the blow, when it is struck, comes home on something solid.



One of the standardized tile pallets that makes a tile of the dimensions recently agreed upon

Inasmuch as the steel surface is flat and true at all times, the mold box can set firmly down on it and thereby eliminate any fin such as comes under the brick when a warped wooden pallet is used. In other words, on the steel pallets a very firm, true and good looking brick can be produced much better than can be produced on the usual wood pallet. The feature is such that the pallets will not slip when placed one on top of the other in any one of four or five different positions.

A double reversible pallet made for some purposes, is the same on the top as the bottom and right and left, that is, it can be put into the machine in any manner in which it happens to come to the machine, as there is no right or left, or top or bottom. It is used principally in connection with cars or lift truck platforms where the surface is flat.

In other installations using certain other makes of equipment, such as the Anchor, Eberling, Shope and some others, it is more desirable to use the single reversible pallet. This is a one-piece pallet of very rugged construction and yet effective as to design. It is merely a piece of No. 6 gauge special steel formed up to the shape.

One photograph shows these pallets in use in one of the plants using the two-wheeled off-bearing truck. It will be noticed that the pallets with the brick thereon are stacked up in tiers of ten pallets each or a thousand bricks to the stack. These are wheeled into the drying room or tunnels on the two-wheeled truck which is shown behind one of the piles. The single reversible pallet can be used with equal facility on a flat top car or platform for use with the lift truck.

Both the double reversible and the single-reversible pallets are made of sufficiently heavy gauge material to absolutely prevent any twisting of the pallet from corner to corner. Therefore no brick will be broken from this cause. The construction being quite substantial there is practically no repair expense in maintaining the pallets and once installed, they should last as long as the plant is in existence.

In the use of any pallet a much better looking and cleaner brick is obtained if the pallets, whether they are wood or steel, are cleaned and oiled. In some plants in which the steel pallets are already in use it is customary to oil them with a sprinkling can, using crank case drippings that can be obtained from any corner filling station. Sometimes this is done every time through the machine and at some places it is customary to oil the pallets about once every other time through the machine.

The cost of the steel pallets would ordinarily run from about one and a half to two and a half times the cost of the wood pallets. If the wood pallet is made of a good grade of material the cost of the steel is usually only about one and a half times the cost of the wood, but inferior wood pallets may be made out of cheap lumber in which the ratio, therefore, will be a little higher.

Making a Business of Products Manufacture

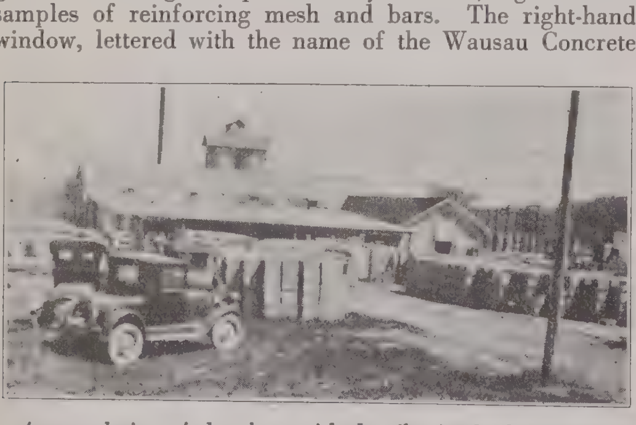
This Wisconsin Firm Considers Itself Just as Important as the Biggest Manufacturer in the City and Acts Accordingly—A Good Product Well Merchandised—Selling Methods—Manufacturing Methods

The Wausau Concrete Company, located in the thriving lumber and granite town of Wausau, Wisconsin, is in the concrete products business. It does not simply make the products and wait for a buyer to come around and respectfully ask for an order. The manufacturing end is run on the attitude that the sales department must have a plentiful supply of good products to sell, and the entire affair is run on a businesslike basis.

Like the other prominent manufacturers in the city, such as the paper mills, the manufacturers of machinery, and so on, this concern maintains offices down in the business district and a prominent display at the main street headquarters of the local chamber of commerce. Perhaps there is a reason for this ostentation. If so, it may lie in the fact that the same concern, under a different name, supplies a line of aggregates and reinforcing steel to local contractors. As material dealers, they have evidently learned that merchandising is just as important as manufacturing, and thus the downtown display offices and the exhibit at the Chamber of Commerce. Then the plant itself is given a sort of good-will advertising value from the fact that everything about it is kept neat, and the structure housing the various departments is easy to see. The stranger coming into the town, and seeing the most interesting display of trimstone, block, culvert pipe and other products at the latter display, will first be steered over to the office of the concern. Here, in an adequate space on the ground floor of a building just off the main street, are located the offices where the sales end of the business is transacted.

The Office

First there are the two neat display windows, on either side of the door, where again the products of the firm are displayed. In the window to the left, on which is the sign of the Wausau Sand and Gravel Company, are jars of the good sand and gravel produced by the firm, together with samples of reinforcing mesh and bars. The right-hand window, lettered with the name of the Wausau Concrete Company, contains the Certificate of Quality, issued to the firm, with copies of the firm's literature and, grouped neatly in the background, more of the concrete units manufactured out at the plant.



A general view of the plant, with the silos in the background, and a yard full of block up to the front. Notice the pipe yard in the right rear.

As the visitor enters the door he is greeted by a comely young lady seated at an oak desk just behind a railing-counter built of the block and topped with the coping manufactured by the concern, which again effectively displays the materials on sale. Upon inquiry, the visitor learns that the office is in charge of C. W. Parsons, president and manager of the firm, and that I. J. Westerveld, secretary and treasurer, is to be found out at the plant, where he supervises production. Since Mr. Parsons is busy, at the moment, figuring on a new building soon to be erected, the caller is invited to make himself comfortable until the president is at liberty. Seating himself on a bench before the counter, his attention is called to a table whereon repose the latest issues of the leading technical papers of the construction industry, a stack of the company's literature, and several copies of the stucco books and other booklets published by the Portland Cement Association and the cement manufacturers.

Soon Mr. Parsons, who is an energetic fellow of the type too often lacking in the smaller communities, is finished with his prospect and comes out to greet the visitor and see how he may be served. A short chat reveals several interesting things, chief among them being that products can be sold strictly upon a quality basis at a price that proves attractive to the manufacturer. Mr. Parsons

Here is the adjustable reel that is used in fabricating the reinforcing cages for the culvert pipe makes it his business to cash in on the certificate of quality that their good products have won them, and all profitable forms of publicity are used. The exhibit at the Chamber of Commerce is one form of good publicity. Then there are two very interesting little four-page booklets, one describing concrete masonry units and the other entitled "Concrete for Culverts—The Solution to Your Problem." The former has a very attractive, and incidentally expensive, cover design illustrating the Wisconsin Valley Fair Exhibition Building, at Marathon Park, Wausau, that was built of 30,000 block from their plant, while in the center spread appears a short sales talk on the use of Wausau block and portland cement stucco. The page bears a picture of the plant, several recent jobs, and illustrations of the common block, rock-face corner block, panel face block and rock face block. The back page gives information about the block carried in stock and tells something about the trimstone manufactured by the company. The culvert booklet is devoted to an illustrated sales talk on concrete pipe culverts, and devotes one page to the specifications of the Wisconsin State Highway Department on concrete culvert pipe. Stock sizes are listed.

The Sales Department

The sales department consists of two salesmen working in and around Wausau, and four local representatives in more distant territories. With this organization, trimstone and even other products are being sold in cities as much as 300 miles distant, on a rather small margin. After all manufacturing, sales and delivery costs are subtracted from the prices quoted the margin is rather limited, and it is found necessary to spend about two-thirds of this amount on advertising.

Now, as Mr. Parsons is a busy man and several contractors are lined up at the counter with blueprints, the visitor must take his leave and proceed to the plant, out on the edge of town. Here, after a short drive through the business section and then out into the industrial part of the north end of town, the plant is reached, the car parked alongside a neatly stacked supply of inspected block, and the seeker of ideas is shaking hands with I. J. Westerveld, who is on the job to see that the best sort of products are made at the lowest possible cost. Mr. Westerveld, who is a former cement company engineer, certainly is on the job. He is the high-grade type of man who is more than ever before interesting himself in the products business, the sort of fellow who always knows what he is doing.

The home-made bucket on the overhead monorail is taking a load of aggregates from the silos to the mixer

At the Plant

Mr. Westerveld is as proud of his plant as he can be, and is glad to take time off to show the visitor around. First the rear of the plant is seen, where the sand and the gravel are delivered by truck from a nearby pit, operated by the sand and gravel part of the company, dumped into a concrete hopper, and elevated to storage by means of a 45-foot bucket elevator. The sand is of good quality, quite clean, and graded up to ¼-inch. The gravel is mostly granite pebbles and contains no soft particles. The aggregates, the visitor finds, are stored in two concrete stave silos, built of Playford staves, which are carried in stock by the company. The bucket elevator discharges into either silo by means of a two-way chute, and the elevator is located midway between the two silos. Both silos are equipped with a steam pipe system for thawing the aggregates in winter.

Mr. Westerveld is quick to explain the desirable space-saving advantage of the silo form of aggregate storage, as well as the fact that but one mixer man can serve three mixers, receiving the aggregates directly from the silos by gravity. The visitor is then taken through a door on the right of the silos that leads directly into the workroom. To the right, upon entering the door, a great stack of cement is to be seen, together with a few plaster molds, while to the left is a long roomy platform that holds the mixers.

The Mixing Floor

A flight of steps leads up onto this platform, where the batches are proportioned and mixed, by one man. At the rear of the platform are the two aggregate silos, each with a gated chute at about eye level, the two chutes converging to a common point centered upon an overhead monorail trolley suspended from the ceiling. This trolley system, which branches into two directions, each branch turning at right angles by an easy curve and running the length of the platform, is provided with a two-way switch arrangement which is thrown by the mixer operator by means of a simple mechanism. This mechanism is operated by two pull-cords. The trolley is of the type manufactured by Richard-Wilcox, in Aurora, Illinois. Suspended from this trolley is a home-made charging bucket, arranged with a bottom dumping gate, designed by the management and fabricated in a local factory to their special order.

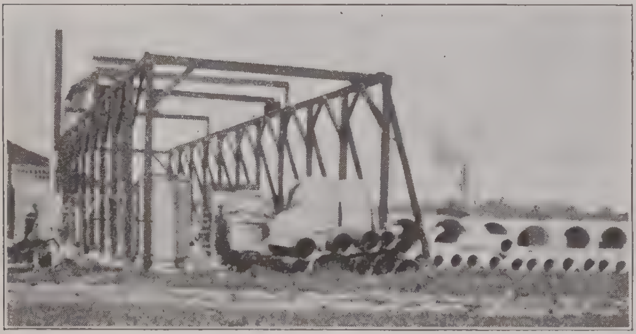
This bucket, whose capacity is 9 cubic feet, is run by hand until it is underneath the chutes on the silos, the gate of the sand bin is held open until the correct amount of sand is discharged into it, the process is repeated for the gravel, and the charge of aggregate is then taken to the desired mixer. The mixer man takes care of this, and moves the trolley-bucket along the monorail system by hand, operating the switch to send the material down the correct track. Underneath the trolley, and set in the platform floor, is a narrow-gauge track running the full length of the platform. On this track runs a small, home-made car with a hopper body. This little car has two uses, one of which is to carry sacks of cement from the storage pile to the mixers, where a small supply is always kept on hand. After the mixer man has let the sand and gravel into the mixer, he picks up the cement from the pile at hand, just delivered by the car, and after opening the sack, dumps the cement into the mixer. The water is then let into the batch and the mixer put into operation. The car is also used to take concrete from any of the mixers and transport it to a convenient point of the platform. This concrete is then dumped into the wheelbarrows which take it to the cast stone department.

Reclaiming Cement

There are three mixers in use, two 9 cubic foot Blystones and a Koehring one-bagger drum mixer equipped with a water tank. The Blystones are used to provide material for the various machines and for making the trimstone, while the Koehring machine takes care of the wetter mixes required for the pipe and for other cast work. The former mixers are located along the outer edge of the platform, so as to feed the block and other machines, while the latter one is located on the far end of the platform above the part of the floor devoted to casting the culvert pipe. Next to the batch mixer, and at the rear of the platform is a home-made bag cleaner, into which cement sacks are put and cement reclaimed for use. This sack cleaner, which is chain and belt driven, consists of a squirrel cage drum set into a wooden box with a hopper bottom. The squirrel cage, which contains four baffle boards, and is covered with a wire netting, will hold a batch of 40 sacks. It revolves at 12 to 14 r.p.m. and cleans the batch in one-half a day, and deposits the reclaimed cement in a sack suspended from the bottom of the machine.

The Pipe Department

The batch mixer is shovel-fed after the aggregates are deposited in a receiving hopper, since lack of headroom makes it impractical to insert the charge directly from the bucket. This mixer discharges its batches onto a platform on the balcony, from where the concrete is shoveled into a pipe mold that is standing on the shop floor a couple of feet away. The consistency used is that that will give a slump of approximately 4 inches. The culvert pipe made in this shop are manufactured according to the specifications of the state highway department.



The pipe yard, with the crane used in stripping the Quinn molds, and a stock of finished pipe curing out in the open

The visitor is then shown how the filled pipe molds are picked up by a Barrett-Cravens lift truck and wheeled out into the yard and stored, still on end, until the concrete has hardened sufficiently to permit the forms to be stripped. He sees how the stripping process is done by means of a small overhead chain hoist carried by a wooden traveling crane, and how the reinforcing steel cages for these pipe are fabricated by one man with the aid of a home-made reel that is easily adjusted to the desired diameter.

The Block Machines

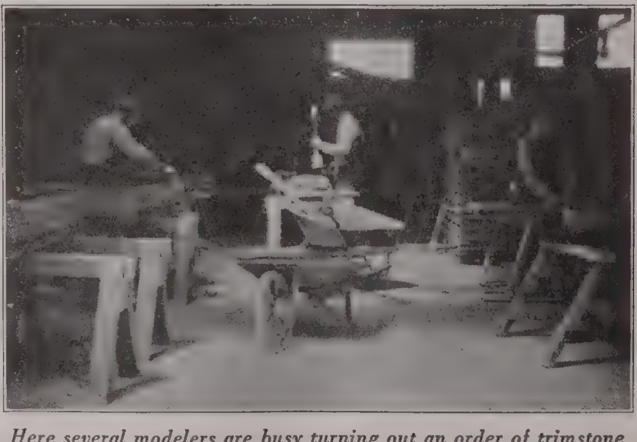
He is then taken back into the plant and shown the department where block and silo staves are pounded out by modern machinery. Here, ranged along the edge of the mixer platform, are one Universal tamper, a Hobbs face-down machine, and a Universal stave machine equipped for making Playford staves. All of these machines are belt-driven, as are the mixers and the sack cleaner, and are all connected to the same overhead power shaft, which is driven by a 15-hp. electric motor mounted up on a roof truss. A second electric motor, of 5-hp. is used to drive the material hoist on the outside.

Home-made wooden racks receive the block and the staves as fast as they are turned out by the machines, and the loaded racks are hauled to the curing chambers on rubber-tired lift trucks. In making the block it is the aim of the plant, the visitor is informed, to turn out the best they are able, and at the same time obtain the greatest yield per sack of cement. Careful attention to proportioning, mixing, tamping and curing, enables them to produce block that have an average compressive strength of 1400 pounds per square inch of gross area, and an absorption of not more than 7 per cent, yet the cement content is unusually low. The secret lies in the use of carefully graded aggregates and ideal curing conditions, according to Mr. Westerveld.

The Curing Rooms

The kilns in which the various products are cured have walls of concrete masonry and roofs of wood. Mr. Westerveld explains that he has been experimenting with kiln roofs, using different pitches and different materials, but has yet to find the ideal design. Steam pipes equipped with petcocks and running in troughs full of water, provide the heat and moisture for curing. A steam pressure of 10 pounds is ordinarily maintained in the steam lines. The time of curing depends upon the state of the weather. After steaming, the block are hauled into the yard, which is paved with concrete, by another lift truck, and the units are stacked neatly in piles of the usual height.

When the visitor has seen this he is again taken back into the shop, this time to the department concerned with the manufacture of trimstone. This space lies between the block department and the kilns, and utilizes about the same floor space as the former department. At one end of this department the molds are made by several experienced pattern-makers and carpenters, and the work moves thereafter in a straight line until the finished units are ready to be carried to their special curing room. The molds ordinarily used have sides of wood clamped together, and sand is used to give the face its shape. This is done by experienced modelers, who put the wood frames on a board on trestles, slip in the wood pattern, tamp in a quantity of damp sand, and then reverse the mold and remove the pattern, leaving the design in reverse in the sand mold. The completed mold is then carried to the next pair of horses, where the special facing mixture is tamped into place and the backing concrete is then rammed in until the mold is filled. This material is brought over from the car on the mixing platform by wheelbarrow. The mold is then reversed and stripped, the sand cut away with the trowel, and the facing given a final finish going over by a skilled workman who uses modeling tools as well



Here several modelers are busy turning out an order of trimstone as a trowel. It is his job to remove any imperfections that can be detected before the work is carried to the kiln. When the piece is at last judged perfect it is picked up carefully by two men and carried gently into the curing chamber and deposited on trestles to undergo its first curing. When the curing period is completed the pieces can then be removed to the yard and given their muriatic acid bath to bring out the colors of the aggregates when that step is necessary.

The entire plant employs but 25 men, and with this crew the producer, according to Mr. Westerveld, can ship out as much as two carloads of block in one day, in addition to normal truck deliveries to jobs in the same city. The production of trimstone is such that some days see as much as one and two carloads moving down the siding. Thus, by the use of sound business methods and by the production of a product that is demonstrably and uniformly good, this manufacturer has succeeded in building up a very profitable business, even though he is in the heart of a region devoted to frame and to granite construction.

A New Cement Brick

Practically a new industry has been introduced in England quite recently. Considerable importance attaches to it in view of the fact that it has given quite a spurt to the cement industry and materially reduced working costs in at least one London distillery. The success of the scheme, it is said, will go far towards encouraging others to follow suit.

The new venture is the production of a cement breeze brick and its origin is somewhat curious and decidedly interesting. For some time past a large London distillery had been seeking an outlet for the great quantities of slack produced from their furnace fires. The distillery managers considered that the breeze which was being wasted might be used commercially, provided it could be turned into some article of general use. They ascertained that a number of cement factories along the shores of the Thames and Medway, in Kent, and within easy access of London, had been inoperative for several years. They conceived the idea of getting these factories restarted to provide cheap cement for mixing with the breeze. The cement is being delivered in London and the distillery has found a most profitable sideline in the production of the cement breeze brick. There is already a large demand for these bricks, which have been found particularly suitable for partitions in office buildings, and similar purposes. The distillery fuel bill is a very considerable item, as much steam has to be raised, and the new production not only gets rid of what was previously waste and cost money to remove, but by its present utilization the amount of the bill is very materially reduced.

Benches a Good Advertisement

Out in the residential districts of your town, where the car service is not of the best, nothing would prove a builder of good-will better than a series of concrete benches at principal car stops. Many a concretor has donated a number of these specialties to his community, and let them carry his advertising, in a useful and welcome manner. They may be made to carry any short message in the concrete sides or painted on the wooden back and seat. Other things that are equally welcome and effective would be sidewalk patches at points otherwise difficult of passage to baby carriage traffic, flower pots for parkway streets, fountain for the park, and other small civic improvements.

Detroit Products Association Takes Important Step

In an effort to establish the manufacture of concrete products on a permanently satisfactory basis, products manufacturers in Detroit and vicinity have inaugurated activities that will promote the welfare of the industry. Whole-hearted co-operation and confidence are the factors that make the inauguration of such a program possible.

The program hits at three fundamental requisites for the success of the concrete products industry—a high standard of quality in the product, the adoption of a fair building code and the strict enforcement of that code.

To insure the manufacture of uniformly high-grade concrete products for the Detroit market, the Association has taken steps to establish its own engineering department whose principal function will be to maintain a strict check on the quality of the product produced by every manufacturer marketing in Detroit. This service is available to all producers regardless of whether or not they are members of the Association. In this work the Association will cooperate in complete harmony with the Detroit Building Department.

To carry out this program, the Association has employed a testing engineer and has purchased equipment and supplied for the proper carrying on of the work, quarters recently having been leased. To cover initial expenditures, a membership fee equal in proportion to the number of members who cooperate in the plan has been provided.

The yearly production of each company has been used in the establishment of a pro-rata basis of assessment to cover the annual maintenance appropriation of $5000. A maximum and minimum fee has been provided, each year's assessment being based on the production of the previous year. A tax of one-half cent per block and one-quarter cent per tile is estimated to be more than ample to carry out the program.

In working for the adoption of a single standard of quality and an equitable building code, the committee appointed to investigate the situation recommended the elimination of the present Class B quality permitting a compressive strength of 500 pounds per square inch gross area. The conformity of all concrete units with the present Class A standard of 700 pounds compressive strength was urged. A strength lower than 700 pounds, the committee report states, does not serve the best interests of the industry and does not allow code requirements to be maintained, while increasing manufacturing costs and restricting sales.

Requirements for this standard are in accordance with the American Concrete Institute standard for Class A concrete building units. The conclusion of the committee was arrived at after a study of the building code provisions of other cities and the recommended standard specifications of several national organizations.

Since the limited size of the field force of the Commissioner of Buildings does not allow much extension of service, the Association took it upon itself to provide ways and means of guaranteeing products conforming to the code requirements. To promote, and not hamper, the progress of the individual manufacturer is the aim of the Association in the employment of a field secretary to visit all construction jobs, selecting samples supplied by the manufacturer.

The water-cement theory, otherwise known as the Abrams Theory, is not an idle dream—it actually works. Within the range of workable mixes, uniform and required strengths can easily be maintained as long as the ratio of water to cement is kept constant. Any good foreman can do it.

New Concrete Bridge Built Around Old Steel Bridge

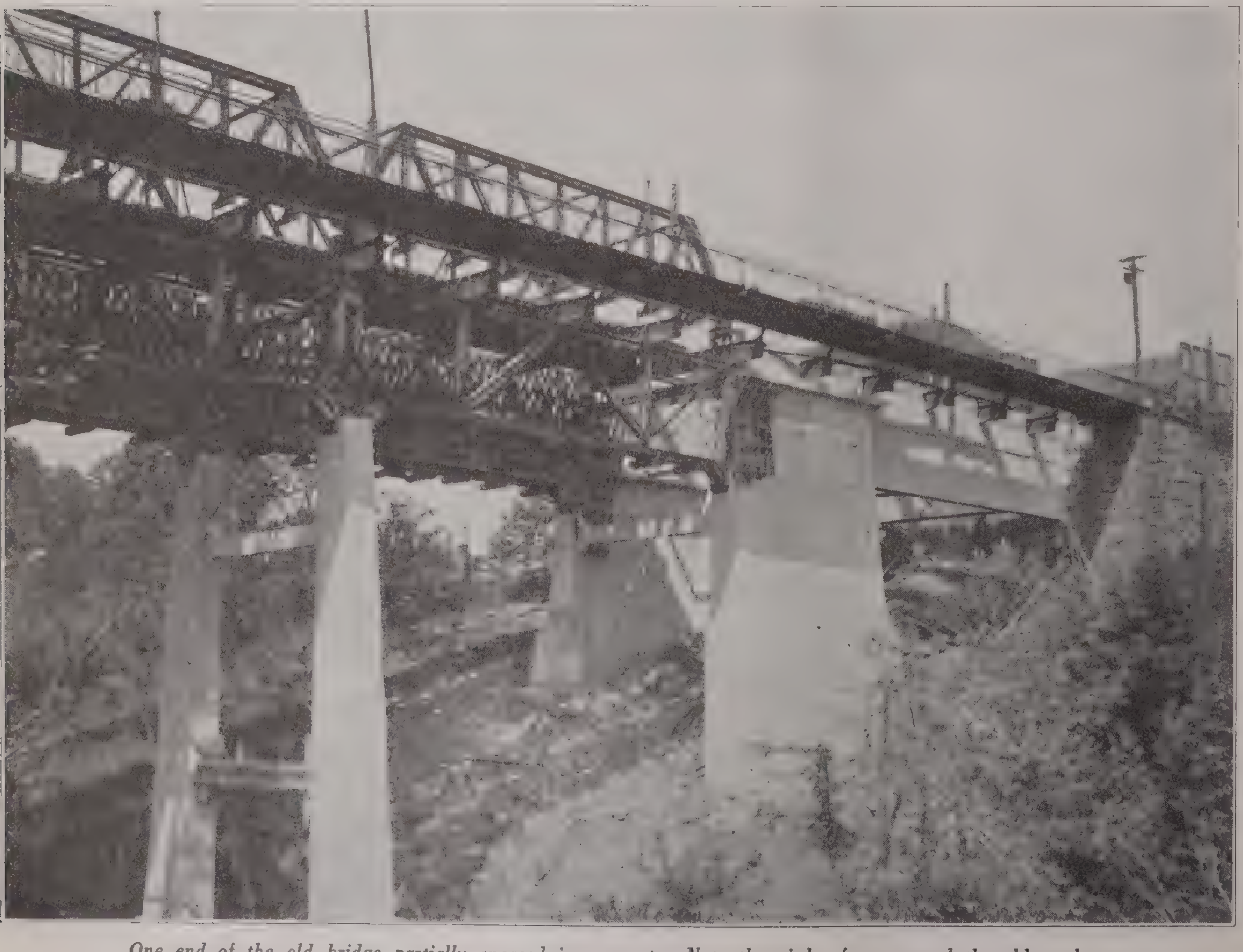
Old Steel Structure, Built in 1892, Transformed into Modern Reinforced Concrete Bridge—Old Bridge Was Used as Core for New Bridge—Traffic Maintained—Use Temporary Trusses to Support Forms — Construction Methods Described—Save $150,000

By JOHN F. HOUGH, C. E.

One of the most interesting projects of bridge construction now in progress in the United States, is the transformation of a wrought iron viaduct into a reinforced concrete structure, in Lynchburg, Va.

The business section of Lynchburg is separated from a very desirable residential section by a deep gorge, which is 130 feet deep and 908 feet wide from the street level. In 1892 a realty company was formed that financed and constructed a wrought iron viaduct across this chasm. Some years later the structure was taken over by the city of Lynchburg. The bridge was designed for light traffic which suited the times and was composed of 10 spans supported by 9, alternating double and single, bents. The second and third spans from the southern or business district end were 90 and 175 feet long, respectively, with the bents constructed askew to parallel the Norfolk and Western tracks and Blackwater Creek that ran obliquely under the bridge. The rest of the spans were approximately 62 feet face to face of bents. The wooden floor of the bridge was supported by transverse built-up I-beams, in turn supported by simple trusses of various lengths and depths. The sidewalks were supported by cantilevers from the ends of the I-beams.

Traffic had been getting heavier and heavier until in



One end of the old bridge partially encased in concrete. Note the girder form around the old steel truss

The old steel bridge as it was when construction started

1925 it was realized that the old bridge was inadequate. Engineers were called in and after much discussion it was decided to transform the old structure into a modern reinforced concrete bridge, using the old bridge as a core or nucleus for the new. To do this meant that the bridge could continue to be used during a portion of the construction by all types of traffic, and all the time by pedestrians. This was very desirable, as it would require a detour of a mile or more to get across the gorge in any other way. And construction costs could be reduced materially by using the old structure to support forms and carry trains of concrete.

One of the new concrete piers

Procedure

The new bridge was designed to incorporate the old for about two-thirds of its length; the other third to be removed when the new bridge was completed up to the floor system. The third portion to be removed is on the north end where the existing bents are askew, and where the spans are of unequal length. The new bridge at this point consists of two arch spans, 132 feet face to face. The rest of the bridge is to be of girder spans, the main girders taking in the existing steel trusses. The bridge is to be 60 feet wide overall, the roadway being 40 feet between curbs and the sidewalks on each side of the bridge 10 feet wide. Its length will be 908 feet, and its height a maximum of 132 feet and will average over 100 feet. The railings will be of concrete, massive and imposing, with concrete light and trolley poles, surmounted by colonial type lights on brackets.

In the design of the bridge the existing steel was figured as having little or no value as reinforcement, and sufficient steel bars were incorporated to insure the proper strength of the structure. The double bents were utilized to make piers 34 feet wide, and the single bents to form rocking towers between the wide piers. Expansion is taken care of by the pendulum wall type, with one inch joints left in the wide piers. The expansion joints in the floor system come directly over the joints in the piers. The main girders are 17 feet deep, 2 feet wide and 60 feet clear span. The floor slab is 5 inches thick. Slots are provided for the double street car tracks. Conduits for telephone and light wires are to be suspended under the floor system.

The whole makes a very imposing bridge with graceful lines.

Pier Foundations

The work started immediately after the contract was let. It was assumed that all of the bents of the old bridge were on solid rock foundations, but this was found not to be the case. The old footings were in all cases stone masonry, 8 by 8 feet square, with 3 by 3 feet cap stones. Some of the footings were unmortared. Six of the footings did not extend to solid rock but rested on red clay. This was apparently sound enough to bear them, for they stood there 30 years. The increased weight of the new bridge required that these footings be extended to rock, and this had to be done without disturbing the traffic on the bridge.

Soundings were made and the excavation started. Holes were made on one side of a footing, going down to solid rock, and sufficient in size to take a concrete wall three feet wide and 15 feet long. After this wall was placed a similar wall was made on the opposite side of the footing. The two concrete walls extended up to about the level of the bearing plate of the steel pier column. Two specially constructed built-up beams were placed across from one wall to the other, one on each side of the column. Steel plates were riveted to the sides of the columns, giving a knife edge bearing on the beams. Two 75-ton hydraulic jacks were then placed under one end of the beams, and the whole column lifted one-quarter of an inch, or until the jacks and beams had completely taken the load off the old footing. The old footing was then taken out, the excavation taken down to solid rock, and the hole filled with concrete high enough to take in the base of the column. After this concrete had set two weeks the beams and jacks were removed and used on another footing.

Another difficult operation was excavating for the foundation of the first pier. This pier is located on the bank of the ravine which is solid sandstone and granite on a very steep slope. The Norfolk and Western Railway runs near the base of this slope, as well as several high tension electrical lines and Western Union Telegraph lines. All of the over one thousand yards, had to fall on the railroad right-rock blasted out of the excavation in this bank, which was of-way, and then be transported across and disposed of farther down the bank. This was all done without the interruption of one train or without injuring any of the wires.

The piers were poured in sections, the forms being of the sliding type and elevated after each pouring

The contractor is using a central mixing plant located under the bridge about at the center. A one-way tower elevator was constructed to a point well above the bridge floor. A railroad spur was run alongside his plant and the aggregate was handled with a clamshell derrick. A belt conveyor carries the cement from the shed to the mixing platform. A one-yard mixer is used, equipped with a Blaw-Knox inundator for the fine aggregate. All concreting within a radius of 150 feet of the tower was done by direct chuting from the tower. For work at a greater distance the concrete was taken up the tower to the bridge floor and there dumped into cars and taken on a narrow gauge railroad to a floor hopper, where it was chuted to the forms. Concrete for the floor system was handled in buggies after it came up the tower.

The piers were poured in sections 8 feet 6 inches high, the forms being of the sliding type, and elevated for each pouring. Triangular beads are used at the top of each our to eliminate unsightly joints.

The main girders as described in a preceding paragraph were too high from the ground to be economically supported by timber bracing, so heavy steel trusses were used to suspend the forms for this work. It was required that 2 adjacent girders should be poured at the same time, so 4 trusses were supplied. These were fabricated on the bridge floor, and the forms for the girders suspended from them with heavy rods. After 21 days the rods are removed and the trusses moved forward to the next two spans. These trusses were each 62 feet long. This is a unique method of supporting forms for girders of such magnitude, but it has proved highly satisfactory.

The tower and the hopper from which concrete is placed in trucks to be hauled by dinky engine to the forms

Proportions

The concrete used in footings was proportioned 1:3:6, the coarse aggregate being crushed limestone graded from one-half an inch to three inches. The concrete for all work above the footings was specified to be proportioned 1:2:4. The fine aggregate was river sand, and the coarse crushed limestone graded from one-quarter of an inch to one inch. The average fineness modulus of the sand being was 3.03; of the stone was 7.27. It was found that the aggregate with the fineness modulii stated above, gave a mix too coarse and harsh to be of a workable, plastic consistency, and that the concrete would not test 2000 pounds per square inch at the end of 28 days. The mix was then altered by increasing the sand and decreasing the stone to give a field mix of 1:2½:3½. According to the calcu-

The temporary steel trusses which support the girder forms

lations this should have made the concrete test at least 2000 pounds or more at 28 days. Actual results bore out the calculations, and the concrete tests rose from an average of 1800 to 2100 pounds per square inch. With the inundation method and with the accurate measuring of the aggregate, absolute control of the mixture was possible and the results have been particularly consistent.

Arch Design

The arches are two full center arches. Each span consists of four ribs and each rib of a span is exactly opposite the rib of the other. The ribs are to be supported by self-supporting steel centering, and a pair of ribs, or one in each span in the same plane, are to be poured together in voussoir sections. The ribs will be very graceful, their depths being 5 feet at the crown and 6½ feet at the springing line. Two pairs are 3½ feet thick, and the other two 4 feet. The reinforcement is the same in the intrados and the extrados.

All material going into the bridge construction is thoroughly tested by chemists according to the method as specified by the American Society for Testing Materials. Concrete cylinders are made from each alternate lift of pier walls, from each girder, from each arch rib, and from the floor slab and handrailing at frequent places.

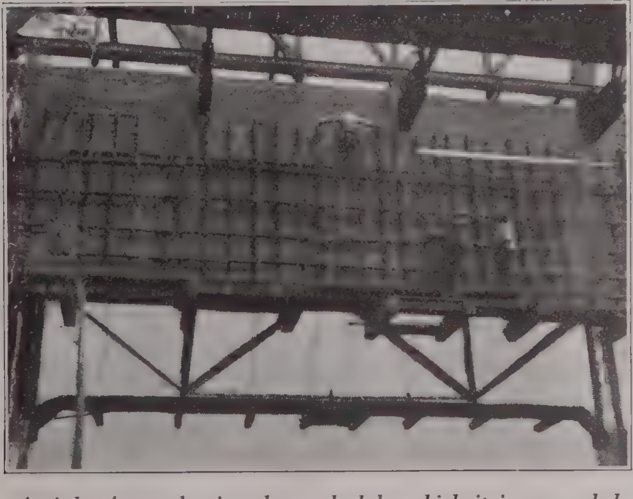
Lime is being used in all concrete going into forms containing any structural members of the old bridge. Tests made to determine the bond and consistency of the concrete around such structural members have been uniformly satisfactory.

The outstanding features of this construction, to summarize, are: The uniqueness of the design; the encasing of an old bridge into a new structure; the height and length of the bridge; the use of temporary trusses to support girder forms; the fact that traffic has been maintained on the old bridge during the construction of the new; and paramount to the city of Lynchburg, the economy of the structure. Using the old bridge reduced construction costs about $150,000.

The old bridge was called the Rivermont Viaduct. In honor of the memory of Edward Beck, the former city manager of Lynchburg, who first conceived the idea of converting the old bridge into a reinforced concrete structure, and who worked so diligently to bring about its final construction, the bridge name has been changed to the Beck Memorial Bridge.

The following quantities are involved in the construction:

14,300 cubic yards of Class "A" concrete.
2,500 cubic yards of Class "B" concrete.
1,300,000 pounds of reinforcing steel, from one-half inch round bars to one and one-quarter inch square bars.
4,000 cubic yards earth excavation.
3,000 cubic yards rock excavation.



A girder form, showing the method by which it is suspended from the temporary trusses

The bridge was designed by Allen J. Saville, Inc., of Richmond, Va., in consultation with A. C. Janni, C. E., and Phillip Aylett, C. E., of New York. The contract was awarded in October, 1925, to the Whiting-Turner Construction Company of Baltimore. L. H. Phillipy was the contractor's superintendent. The writer is in charge of the work as resident engineer for Allen J. Saville, Inc.

A. G. C. Mixer Bureau Discusses Problems at Milwaukee

At a session of the Mixer Manufacturers' Bureau of the Associated General Contractors held in Milwaukee, an opportunity was given for the discussion of many major subjects commanding the attention of that body. Election of members of the board of governors held an important place on the program.

The following elections to the board were made: To serve for one year: Chairman—Harold E. Smith, T. L. Smith Company, Milwaukee; G. C. Ellis, Ransome Concrete Machinery Company, Dunellen, N. J.; Philip Koehring, Koehring Company, Milwaukee. To serve for two years: C. F. Messinger, Chain Belt Company, Milwaukee; O. G. Mandt, American cement Machine Company, Keokuk, Iowa.

The subject of designation of a standard paving mixer of small size was given consideration. It was announced that replies to the questionnaire addressed to 292 city engineers have been received and are being studied in an effort to secure definite knowledge concerning the actual field demands. The matter has been turned over to the technical committee of the bureau, which was instructed to report on the subject at the next meeting.

General Marshall addressed the meeting, outlining the benefits of cooperation among manufacturers and contractors and pointed out the importance of equipment to the contractor.

Clean Up Week

The Wisconsin Concrete Products Association has inaugurated a "clean up week" for plants in its membership. In his weekly letter to members, A. P. Kuranz, the secretary of the association, says:

"A clean yard and a clean plant usually indicate that the manufacturer is up-to-date and progressive and since the slack season is either upon us or soon to come, it would be a good time to clean up both in and around the factory.

"The passing public will get a much better impression of your plant and naturally this will be reflected in your product. Lets all keep this fact in mind during the next few weeks."

Mr. Kuranz' suggestions are equally applicable to all plants, whether members of the Wisconsin Concrete Products Association or not.

Ship Cement on Big Barge

Cement for highway work in Illinois is being shipped on big barges from Hannibal, Mo., to its destination. The barges move down the Mississippi River and then up the Illinois River. Ten thousand tons of cement can be hauled on the big steel barges used.

Concrete Skeleton Frames Speed School Construction

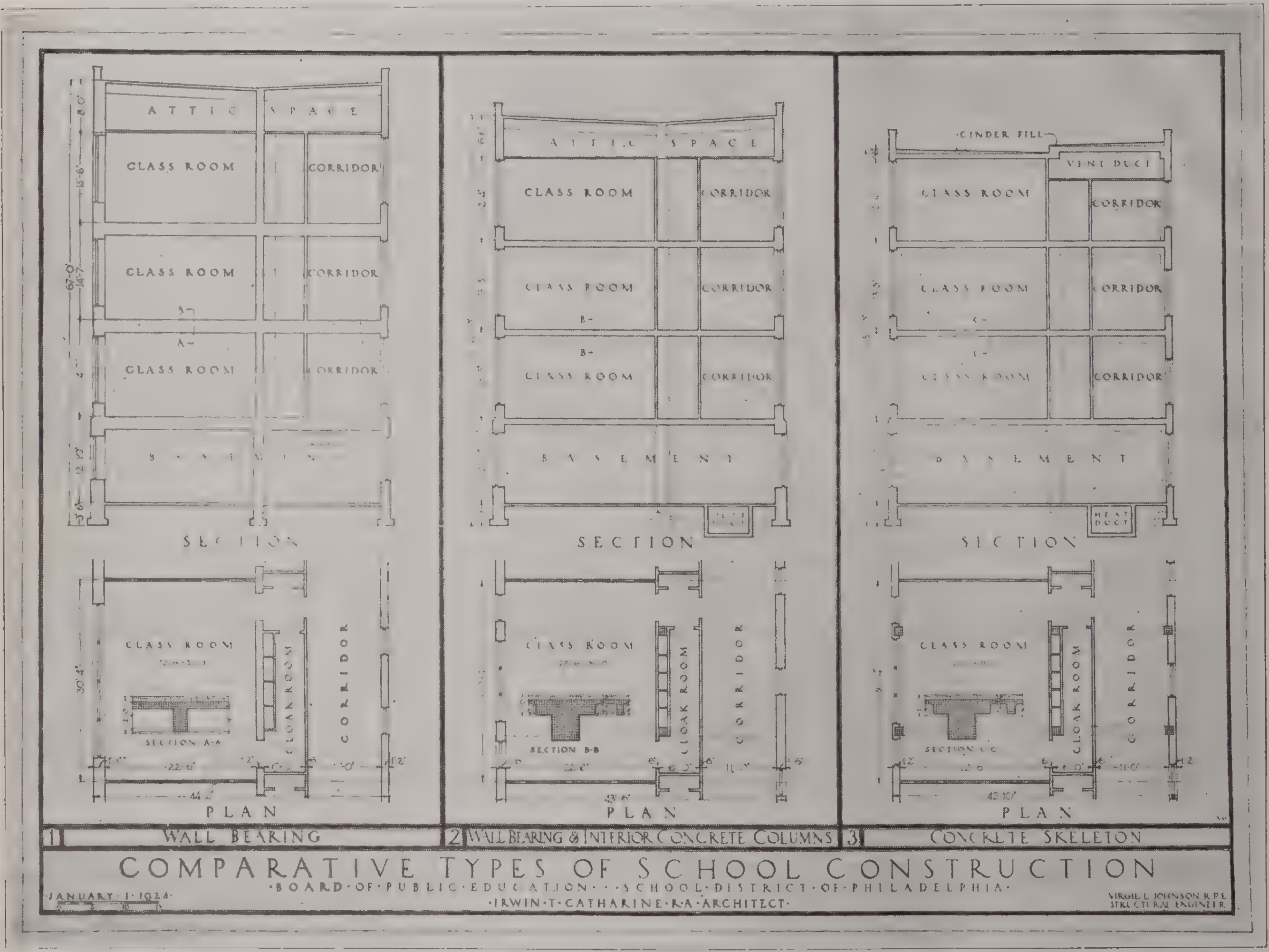
Methods Used by Philadelphia Board of Public Education in School Construction — Skeleton Frame Type Adopted — Speed of Construction — Factors Influencing Design—Economy—Field Control of Concrete Work—Details of Concrete Construction

By **VIRGIL L. JOHNSON**

IN the last few years the Board of Public Education of Philadelphia has made vast improvements in building construction. Much of this progress has been due to the almost general adoption of the concrete skeleton frame type of construction for school buildings.

Under the supervision of John D. Cassell, Superintendent of Buildings, the Philadelphia School Board have built schools fully equipped and accepted within a period of 10 months after commencing excavation. The usual time required for buildings of this size when the wall-bearing type is used was from 18 to 20 months—practically double the time now required. Thus better fire-resistive buildings have been built at a minimum cost and with greater speed than ever before.

Several features have contributed to this favorable condition. Of course, the first requisite is a complete organization. This the Philadelphia board has in its structural, architectural and mechanical departments, carried on under the management of the architect of the Superintendent of Buildings. But aside from this co-operation of the various departments, the outstanding feature is the form of construction used by the Philadelphia board, generally known as *skeleton concrete construction.*



Comparative types of school construction. The concrete skeleton type is now used almost exclusively in Philadelphia

School Design Requirements

There are certain fundamental principles which must be considered in every step in the design and construction of school buildings. Some of these principles are regulated by state laws, such as size of class rooms, heat and ventilation, floor and window space, etc. And in addition to these there are other requirements that must be considered as basic and which are equally as important. They are (a) circulation, (b) acoustics, (c) supervision and (d) rigidity of construction.

(a) Circulation has to do with the planning or grouping of the different activities in such a manner that there may be a minimum amount of lost time for the pupil or instructor in going to and from the central activities of the school.

(b) The acoustics of every room as well as of the corridors must be considered. It requires considerable care and the architect must be concerned with the surface and covering of all floors, walls and ceilings, as well as their shape and contour if he wishes to avoid "reverberation," "dead spots" and "focal points."

(c) Supervision. All rooms and parts of the building must be so arranged that supervision can easily be conducted without taxing the work of the faculty.

(d) Rigidity of Construction. Concrete construction of the monolithic type is especially well adapted to school construction because it is absolutely necessary that there be no vibration of any part of the building, either from school activities or from the traffic of the street or subway. The marching of children, dancing or gymnasium practice should in no way cause annoyance to classes in adjoining rooms, or in rooms immediately below.

All the foregoing laws and principles must necessarily affect the plan and design of schools; also, they create problems and limitations in construction that the engineer must meet. These requirements necessitate a building so complicated in structure that much delay may be caused in its actual construction if means are not taken to avoid it.

Concrete stairways are built at the time the floor slab is placed and serve as a means of safe communication for workmen

Skeleton Concrete Construction

Because of these restrictions the architect is forced to standardize his designs, at least insofar as layout and structural features are concerned. An arrangement of class rooms, flues, cloak rooms and corridors that will be economical and convenient must be found and in the end the best arrangement will be adopted. The application of standardization in the erection of school buildings through the aid of skeleton concrete construction is beneficial to the owner, the builder and the architect. It benefits the owner because it gives him rigid construction with low costs at minimum insurance rates. It benefits the builder because it insures scheduled, speedy work and it is beneficial to the architect because it permits of economical arrangement.

Roof slab of Mary C. Wister School completed three months 19 days after breaking ground

Three types of construction—wall bearing, wall bearing with interior concrete columns and skeleton concrete construction—have been used. (See illustration.) The advantages of the skeleton concrete type are so pronounced that it is now used exclusively for new buildings. This type permits very rapid work. Structurally it has many points in its favor, such as stiffness, economy of space, and concentrated, fully determined load pressures on soil.

In general, the class rooms are usually 30 feet long in the clear so that the spacing of columns is 15 ft. 2 in. The floor and roof construction is formed of 5½ in. wide concrete joists (usually 8½ in. deep) 26 in. on centers with slabs 2½ in. thick. This "composite" floor construction frames into a large girder 16 in. wide by 26 in. deep, which in turn spans from column to column across the width of the room.

The slabs and joists are "formed up" by the use of No. 12 gauge removable steel forms which may be removed in four days after the concrete is placed, providing the supports under the joists are left in place. This permits the continuous use of the forms so that a comparatively small quantity will be sufficient for the entire building. The finished ceiling of the class rooms, corridors and other rooms are formed by expanded metal lath suspended beneath the soffit of these joists and plastered with the usual three-coat work.

The ceilings of the upper stories are formed by similar ceilings supported on channels or angles which are suspended several feet below the roof construction. The space between the roof and the ceiling below is useful for steam pipes and ventilating ducts which are so necessary in large school buildings.

All exterior walls are formed of a veneer of face brick with a backing of a hollow tile or common brick supported at each floor on concrete spandrel beams which are framed monolithically with the floor, girder and column construction. An important feature of the construction is the all-concrete stairways which are poured monolithically with the floor construction, providing safe and easy access to all parts of the building. This feature facilitates the work of other contractors.

Economy of Space

The skeleton frame type of construction is economical in space both with regard to floor area and height.

Because of the 13-in. curtain walls and the 4-in. tile partitions used in place of heavy bearing walls, the total area of a building of this type is reduced 3 per cent. Also because of the shallow floor construction and the omission of large factory-like window openings, the height of each story is reduced 1 ft. 2 in., so that the total height of a three-story building is 5 ft. 6 in. less. This reduction of height creates a saving of brick, tile and plaster work as well as eliminating two risers in each story run of stairs. This means a total reduction in cubature of 10 or 11 per cent in the entire building.

Rapidity of Construction

The rapid construction of any building is best accomplished when all classes of trades working on the building can proceed independently of each other and without interference. In this, skeleton concrete construction is always at an advantage because floor after floor can proceed without waiting for the bricklayer or the stonemason.

Records of the Philadelphia School Board prove conclusively the advantages of this type of construction in the matter of rapidity. A four-story school building was completed and available for use within 10 months after the work was started.

The Thomas Jefferson School, four stories in height, with a cubature of 1,168,188 cu. ft., has the following record:

Excavation started January 28.
First floor slab completed April 15.
Second floor slab completed April 28.
Third floor slab completed May 12.
Fourth floor slab completed May 20.
Roof completed June 7.
School opened December 1, about 10 months after breaking ground.

The Mary Channing Wister School has an even better record. It was accepted by the board in 9 months, 21 days, after breaking ground. This school has 758,000 cu. ft. Both schools cost slightly less than 44 cents per cubic foot.

Economy of Construction

It is easy to visualize the economy in the cost of a building similar to the Thomas Jefferson School when the fact is taken into consideration that the cubature of this building is 11 per cent lower than it would have been if other types had been used. The cost of the building, therefore, approximates also 11 per cent lower.

The general contract for this school, built at Fourth and George Streets, amounted to $427,427. On the basis mentioned above the saving to the Board of Education on this building alone is $47,021 over the wall bearing construction.

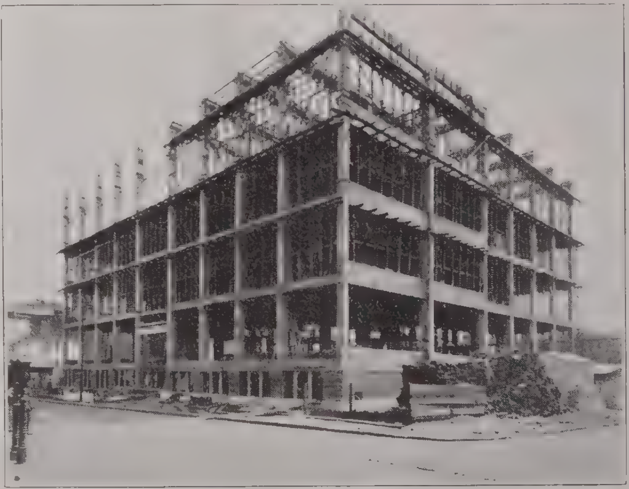
The contractor also gains by the use of this type. Assuming that the contractor's overhead charges amount to $1,000 per month, covering such items as those of concrete foreman, brick foreman, carpenter foreman, watchman, labor insurance, timekeeper and job telephone, the saving to the contractor is considerable.

The Thomas Jefferson School was completed eight months earlier than a similar building of the wall bearing type, making a saving on overhead of $8,000. To this must be added interest on, say, $100,000 for eight months at 6 per cent—$4,000. The total saving to the contractor is therefore $12,000—nearly 2 per cent of the contract price.

Field Control of Concrete

During the construction of the buildings the control of

Thomas Jefferson School 47 days after starting excavation



The Thomas Jefferson School 108 days after breaking ground

Thomas Jefferson School. The building was completed and opened as a school ten months from date of breaking ground the concrete work is under the supervision of the board's inspectors. They make daily and weekly reports to the office of the Superintendent of Buildings. Besides the laboratory test of each carload of cement, the inspector makes test specimens of the concrete. Three samples are made for each 100 cu. yds. of concrete. These are prepared according to the specifications of the A. S. T. M. and are tested for compression at the age of 28 days.

Slump tests are taken from time to time in order to check up the consistency of the concrete. Inspectors are instructed to insist on a 4 to 5-inch slump for floors and a 2½-inch slump for footings.

Class room floors are designed to carry a live load of 75 pounds per square foot, while the auditorium, gymnasium and corridors carry a live load of 100 pounds per square foot. Minor rooms such as locker rooms, cloak rooms, offices, etc., are designed for 40 pounds. In many cases the roof is designed to be used as a playground and computed to carry a live load of 100 pounds. Thirty pounds live load is sufficient for the ordinary roof.

Lunch room and locker room floors have a wearing coat 1 to 3 concrete mortar 1 inch thick, placed over the 2 inches of concrete fill.

The specifications are all written and issued by a separate department, but working in conjunction with all of the other departments so that there may be no overlapping work. Before final issue of any specification each department goes over and checks that particular part of the work with which it is directly concerned.

This is done by the use of a master specification which notes all conditions entering into former work. Notices of changes or special items to be included in new work are given to the specification writer by the various department heads on special memo slips made for the purpose.

All specifications for new work are printed in the Board of Education's print shop and usually make a book of about 300 pages.

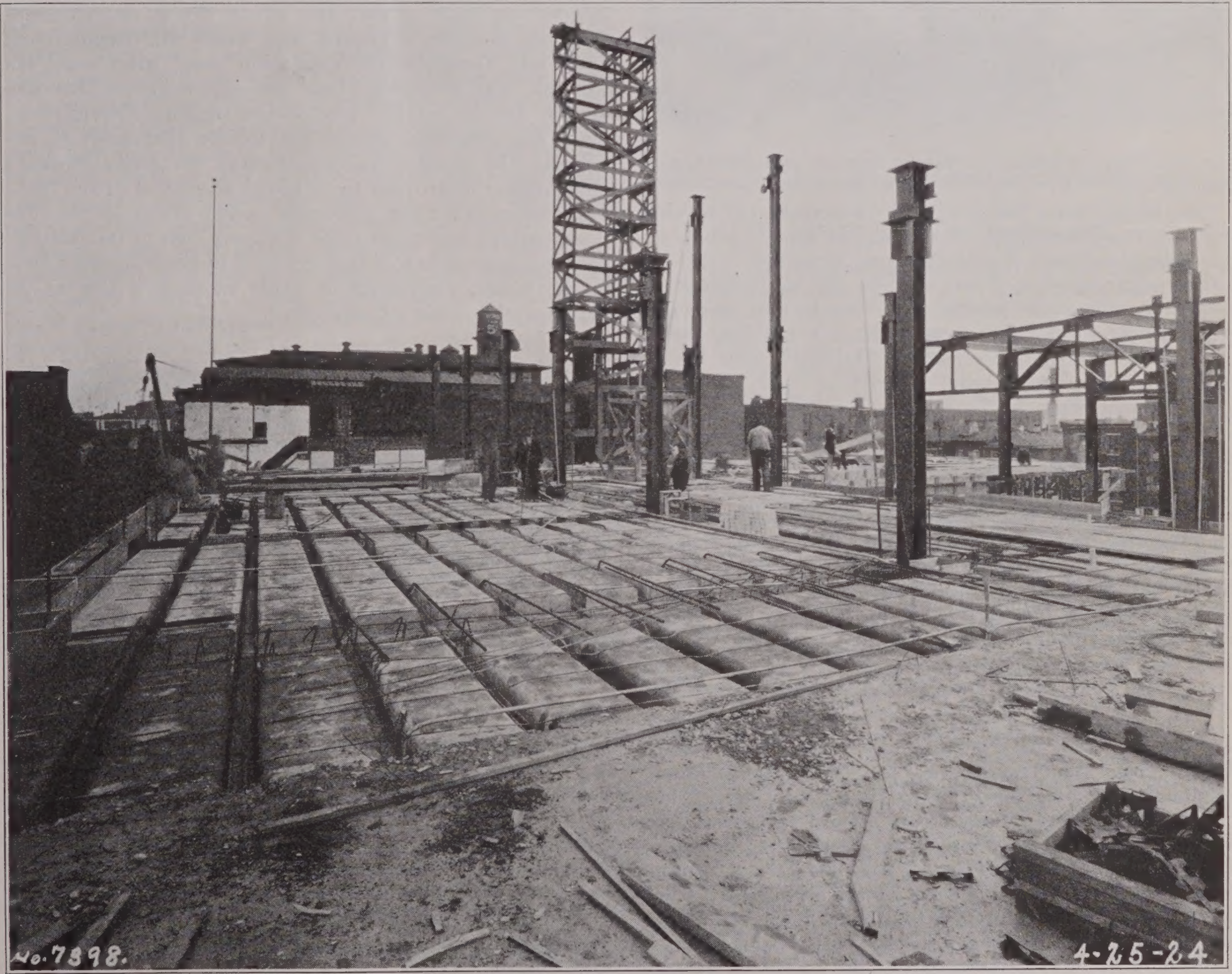
Samples of materials to be used in new work as called for in the specifications are submitted by the various contractors in duplicate; one for an office record and one for the inspector on the work.

In addition to the specifications and the periodical bulletins which are issued to the inspectors from time to time there is being prepared by the Structural Department a manual called "Instructions to Inspectors in the Field." This book is designed to assist the inspector and to supplement the specifications.

Besides the test the manual is augmented by over 100 drawings which fully illustrate many phases of construction details. In some cases they show very plainly the right, as well as the wrong methods, of construction in contrast.

At the present time the Board of Education has 22 buildings of the type described under construction. The 1926 program calls for construction valued at approximately $12,000,000.

In the preparation of this article, the writer wishes to express his appreciation to two of his co-workers for their helpful suggestions—Mr. Irwin T. Catharine, architect, and Mr. Paul L. Boyd, specification writer.

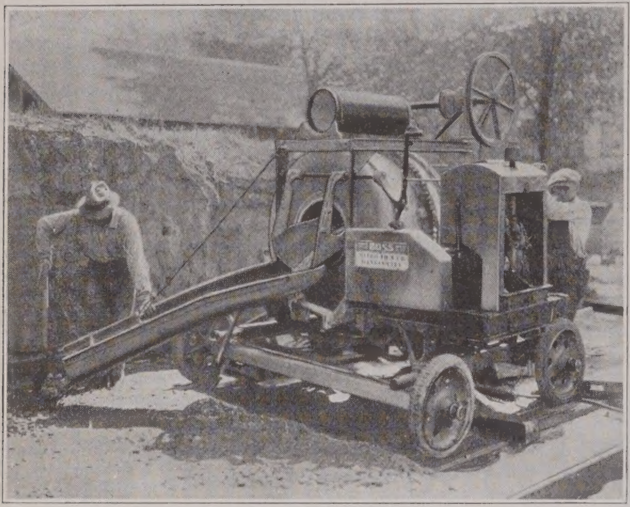


First floor framing, showing use of metal forms seventy-eight days after commencing excavation

New Equipment

Crosswise Trucks are Handy Equipment on Boss Mixer

A feature of the Boss mixer illustrated, manufactured by the American Cement Machinery Co., Inc., of Keokuk, Iowa, is the truck arrangement. By merely slipping the wheels off, special axles with spindles are slipped on the axles and wheels and put on the cross spindles. This simple operation converts the mixer into an end-discharging machine.



One of the axles has a pivot arrangement for turning the corners when towing. It is but a 10 minute job to remove the attachment if side discharge is wanted.

The mixer illustrated was used by the Kelly Construction Company of St. Joseph, Mo., and by the cross-wise truck arrangement was converted from a building mixer to an end-discharge alley paver. The mixer uses a two-bag mix and gives a daily capacity of over 100 cubic yards of concrete.

The Milburn Paint Spray

A handy piece of equipment for painting concrete walls or spraying concrete floors is the Milburn paint spray. In operation the paint enters a large chamber surrounding the air nozzle, from which it is atomized and expanded. Atomization is regulated by a turn of the nozzle from a small to a large spray or is entirely shut off, bringing into play a stream of air for dusting purposes.

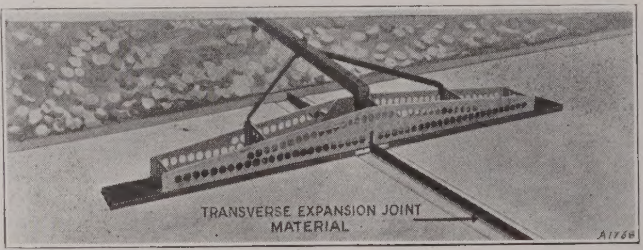
A Balanced Air Compressor

On construction jobs, in quarries and in shops, excellent use can be made of the Angle Compound Compressor, Type WJ-3, manufactured by the Sullivan Machinery Company of Chicago, Ill. This is a motor-driven machine of capacities ranging from 400 to 800 cubic feet. The distinctive feature of this compressor is the high pressure and low pressure cylinders mounted at right angles to each other, in which both pistons are actuated from one crank. The air is compressed first in the horizontal cylinder and then travels through a three-pass, counter-current water intercooler to the vertical cylinder where it is further compressed.

A Straddle Float and Straight Edge for Better Finishing

The paving contractor has usually found himself in for some expensive handwork in finishing the concrete slab at expansion joints and has often had to rely upon makeshift floats to obtain a job that would pass inspection. There is now available, however, a very handy tool that will not only make this part of the finishing easy, but that will meet the requirements of the highway departments and that will stand long use on the job without becoming warped, racked, or otherwise rendered unfit for us.

The tool illustrated here was recently developed by the Walstad Machine Company of Tacoma, Washington, in compliance with requests coming from engineers who were having trouble on highway work and who wanted a tool that would be an improvement over those hitherto in use. This straddle float consists of an aluminum alloy backbone, galvanized sheet iron side members and steel shod finishing boards, assembled in such a way as to afford complete stiffness and resistance to racking or warpage. A grooving plate on each side of the slot at the center of the float provides a groove, into which all surplus concrete left alongside the expansion joint filler may be worked. The grooving plates are adjustable so that the groove can be set for any desired depth. Provision is made for attaching any length handle that may be required. The wooden finishing boards are easily replaceable without destroying the original alignment of the tool. This device is six feet wide and weighs about 36 pounds. A companion tool to this one is the six foot metal straight edge, an inspectors tool that is useful in checking the finish at the joints, and which is made in such a way as to permanently retain its alignment.



The Walstad six-foot metal straddle float that is proving a handy tool on the west coast.

New Surface Treatment for Products

A new liquid preparation for application on concrete, that acts as a hardener, waterproofer, bonding agent, and polish, has been announced by George Witty, chemist, Jenifer Building, Washington, D. C.

According to the inventor, tests have shown an increase in strength of 37 per cent, a decided waterproofing effect, a material reduction of the freezing point of the concrete, a good bonding action with old concrete surfaces, and the possibility of obtaining a polish similar to that given natural marble. Penetration is claimed to exceed 7/8-inch in the average concrete.

Mixer Musings

Reported by "Joe"—The Mixer Boss.

Maybe There's Something In It

"The bass are hittin' fine," says Jim to me the other day, as we run into each other at the smoke shop. Jim, you know, runs a products plant in our town and likes to wet a line and spin a yarn with the best of them.

"What's that got to do with the products business?" I returned, being afraid of another one of those fantastic lies to which this fisherman is addicted.

Jim merely brushed past me, went in for a fresh package of that pipe fuel which the package doesn't even say is tobacco, came out again, pulled me by the arm, and made me sit down on an upended beer case that was there by the curb. "Here's the yarn," sezze.

"The news that the bass were starvin' for a few minnows was what pulled me up to the lake last week, and it's that news that made me stumble onto this thing that I want to tell you about," said Jim. "It was when I was flivverin' up that way that I bumped into a little block plant in a town of twenty-odd thousand where they were trying out for themselves a new way of getting stronger and more uniform block. They'd heard the structural men, at recent conventions, talk about water-ratio and thought they would try it for themselves, and see just what would happen. To make a long story short, they reduced their water content and found the block weaker, they increased their water content and found their block stronger—which is just the opposite to what happens with your structural concrete—and then they began to figure it out. It seemed that the books on the table said that that was just what would happen, since block are made very dry, where the water-strength curve goes up instead of down, so they knew they were right and went ahead. Then they figured out a fineness modulus that was about right, and they figured about how much water and cement were needed to give them the right strength, and then began to make a few more block. First they were too wet and slumped on the racks, so less water was used, and more course aggregate was tried to make up for the loss of strength. Several tries showed them where they were at, and things were ready for production. It was not long before a little adjustment of aggregates made all corrections that were necessary, and they found their yield per sack was climbing quite nicely. At the same time, builders say the blocks are stronger, and their greater uniformity made laying and plastering that much easier, so the block were worth more money to them. It's all worked out very nicely, for the block man and his customer, but it seems too good to be true.

"That's interesting," I remarked, "but it must be true. We all thought it impossible, in our work, until we tried it out. Why not give it a whirl?"

Jim just grunted and walked down the street, with his head forward just like he was doing a bit of thinkin', and leaing me to get back to the job.

They tell me that folks never liked the taste of tomatoes until they started to eat them. The same thing is true about a lot of things in the concrete game. If you doubt it, maybe I can be of help. Anyway, let's hear from the whole gang. Yours till next time.

JOE,
The Mixer Boss.

News of the Industry

Fred F. Lincoln Leaves Concrete After 22 Years' Service

Fred F. Lincoln, for many years Secretary of the Concrete-Cement Age Publishing Company, and representing CONCRETE in the east, with offices in New York City, has now severed his connection with the Concrete Publishing Company, present publishers of CONCRETE, and is spending the summer in Europe.

Mr. Lincoln, who graduated from the University of Vermont in 1897, Phi Beta Kappa, started with the *Cement Age* when publication of that journal was begun in 1904, the same year that CONCRETE was started in Detroit. Prior to his joining this publication he was employed on the *New York Sun*. When *Cement Age* was merged with CONCRETE, in July, 1912, Mr. Lincoln became Secretary and New York manager of the newly formed Concrete-Cement Age Publishing Company. In 1916 the journal took its present name, CONCRETE. Mr. Lincoln relinquished his title as Secretary when CONCRETE was purchased a year ago by the Concrete Publishing Company, the present publishers of the journal.

The vacancy left by Mr. Lincoln's resignation is being filled by Arthur E. Hooven, whose offices are in Room 1401, Pershing Square Building, 100 East 42nd Street, New York City.

With the Manufacturers

The Osgood Company has purchased from the receiver of the *Fairbanks Steam Shovel Company*, at Marion, Ohio, the good will and all the assets of the Fairbanks Steam Shovel Company, such as patterns, records, drawings, formers, etc., together with the entire stock of material that was on hand for the manufacture of steam and gas shovels and dredges.

The purchasers are prepared to furnish from the records and drawings now in their possession repair parts for Fairbanks machinery and equipment that is now in the field.

Mr. Charles Melvin, who was connected with the Fairbanks Steam Shovel Company for 24 years, has been retained by the Osgood Company and placed in charge of the department for handling service and repair parts on Fairbanks machines.

It is understood that there are possibly 400 Fairbanks dredges in the field. All owners of dredges or other Fairbanks equipment are requested to write to the Osgood Company, giving the present location of their machinery, its size and number, in order that prints, drawings and other records may be properly placed in shape for the expeditious handling of repair orders when received. Correspondence relative to equipment of Fairbanks manufacture should be addressed to the Osgood Company, Marion, Ohio.

Effective May 22, Mr. H. E. Gilmore will become manager of the St. Louis branch of the *Timken Roller Bearing Service and Sales Company*. Mr. Gilmore's promotion follows several years sales experience with this company under the direction of Frank J. Lemper, manager and district supervisor of the Chicago branch.

The Omaha branch office of the Timken Roller Bearing Service and Sales Company, formerly located at 2524 Farnum Street, now occupy larger quarters at 2240 Douglas Street. Complete service stocks for authorized distributors will be maintained as in the past. The management will continue under the direction of A. D. Hackim.

The new home of the Los Angeles branch of the Timken Roller Bearing Service and Sales Company will be at 1361 South Figueroa Street, moving to this location from 1241 South Hope Street.

New Books

A Bibliography on Chemistry and Chemical Technology, 1900-1924, by Clarence J. West and D. D. Berolzeimer, is announced by the National Research Council, Washington, D. C., as their Bulletin No. 50 (303 p., $2.50). This work is composed of the following sections: General Bibliographies, Abstract Journals and Year-Books, General Indexes of Serials, Bibliographies of Special Subjects and Personal Bibliographies. As the title indicates, the work is a compilation of bibliographies published as separates, or at the end of books or magazine articles, as footnotes to the same, on the numerous aspects of pure and applied chemistry. Each entry gives name of author or compiler, title, and place of publication. The majority of the entries state the number of references, thus giving an indication of the completeness of the particular bibliography. The entries are classified under the proper subject headings, alphabetically arranged. The duplication of individual entries has been largely avoided by the liberal use of cross-references. An approximate analysis shows that there are about 2,400 subject headings, 7,500 author entries and a total of 10,000 individual bibliographies. Although no claim is made for the completeness of the compilation, it is believed that the work will furnish a convenient starting point for any bibliographic search.

Industrial Literature

"Industry's Electrical Progress" is the title of a very interesting publication issued by the *Cutler-Hammer Mfg. Co.*, pioneer manufacturers of electric control apparatus, Milwaukee, Wis.

The author starts out to prove that the competitive advantages, which electric power brings to industry, lies in the effectiveness with which electricity is utilized. He does a good job of it and has produced a book which any business man connected with a manufacturing company should read.

After showing that the consumption of electricity for industrial purposes has increased 3000 per cent since 1905—and almost doubled since 1921, the book points out the progress which has likewise been made in electrical equipment, particularly in motors and motor control apparatus. Then it gives numerous examples of the wondrous accomplishments of correct motor control equipment. Many photographs of actual installations are shown.

Altogether, the book is one worth reading and worth keeping. The Cutler-Hammer Mfg. Co. offer to send a free copy to any one requesting it on their letterhead. The address is 108 Twelfth Street.

Permeability of Stone, by D. W. Kessler, is the title of a recent technologic paper, No. 305, of the United States Bureau of Standards. This booklet describes a new apparatus developed at the Bureau that is being used to measure the permeability of discs of stone and other non-metallic mineral building materials, and cites a few tests on stone that have been made with the new equipment. Permeability is measured as the amount of water which will flow through a unit area of unit thickness in unit time under unit pressure—difference between the two faces of the specimen. The water that flows through the specimen is measured volumetrically in some cases, and in others must be absorbed by a desiccant and then weighed. The use of the new apparatus by various laboratories is expected to reveal interesting facts about building stones, concrete, clay products, and waterproofing materials, and may prove to be a more scientific and reliable apparatus for the conducting of such tests.

Construction and Construction Materials.—A Summary of Leading Developments During the Year 1924 is the title of a booklet recently issued by the United States Department of Commerce through the Government Printing Office. This contains data reprinted from the Commerce Yearbook, 1924, issued by the same bureau. It contains statistics on lumber, portland cement, structural steel, clay building materials, building stone, aggregates, a paragraph on the simplification of building materials, and a chapter on construction activity and costs for the same year.

Specifications for Fire Tests of Building Construction and Materials, are covered in a printed report presented at the recent meeting of the National Fire Protection Association, which was held at Atlantic City during May. These specifications, which are derived from the experience of the Underwriters' Laboratories and from others who have conducted fire tests in the past, were prepared by the Sectional Committee of the American Engineering Standards Committee, of which Ira H. Woolson is chairman. The specifications are in the nature of a revision of the original specifications adopted some years ago and have reached the point of being named as the A. E. S. C. American Standard. Copies may be secured from the association at 40 Central Street, Boston, Mass.

Organizations

American Concrete Institute; **Harvey Whipple, Secretary, 2970** West Grand Blvd., Detroit.

American Concrete Pipe Association; **M. W. Loving, Secretary,** 33 W. Grand Ave., Chicago.

American Construction Council; **Dwight L. Hoopingarner, Executive,** 28 W. 44th St., New York City.

American Engineering Standards Committee; **Dr. P. G. Agnew,** Secretary, 29 West Thirty-ninth St., New York City.

American Road Builders' Association; **Wm. H. Connell, President,** Miss E. A. Birchland, Secretary, 29 W. 39th St., New York City.

American Society for Testing Materials, C. L. Warwick, Secretary-Treasurer, Engineers' Club Building, 1315 Spruce St., Philadelphia, Pa.

Associated General Contractors of America; **D. H. Sawyer** Secretary, 1038 Munsey Bldg., Washington, D. C.

Associated Metal Lath Manufacturers; **123 West Madison St.,** Chicago; **Wharton Clay, Commissioner.**

Building Officials Conference: H. E. Plummer, President, J. F. Downey, City Hall, Cambridge, Mass., Secretary.

Concrete Reinforcing Steel Institute; **M. A. Beeman, Secretary,** Tribune Tower, Chicago.

Concrete Products Association; John E. Powers, President, Sterling, Ill.; D. R. Collins, Secretary, 47th and State Streets Alois postoffice, Milwaukee, Wis.

Iowa Concrete Products Association; H. E. Meier, President; R. L. Gavin, Secretary-Treasurer, 405 Hubbell Bldg., Des Moines, Iowa.

National Association of Building Trades Employers; **A. E. Coleman, President, 37th St. & Stewart Ave., Chicago. A. W. Dickson,** Executive Secretary, 214 Electric Bldg., Cleveland, Ohio.

National Association of Builders' Exchanges; **William F. Chew,** Baltimore, President; **Earl F. Stokes, Secretary, 15 East Fayette** St., Baltimore, Md.

National Crushed Stone Association; J. R. Boyd, Secretary, 751 Earle Building, Washington, D. C.

National Housing Association; **Lawrence Veiller, Secretary and** Director, 105 East Twenty-second St., New York City.

The National Lime Association; **Burton A. Ford, Secretary, 918** G Street, N. W., Washington, D. C.

National Slag Association; H. J. Love, Secretary-Treasurer, 933 Leader-News Building, Cleveland, Ohio.

National Sand and Gravel Association, V. P. Ahearn, Executive Secretary, 1045 Munsey Bldg., Washington, D. C.

Ohio Concrete Products Association; **G. M. Friel, Secretary-**Treasurer, 2284 North High St., Columbus, Ohio.

Portland Cement Association; **William M. Kinney, General Man**ager, 33 West Grand Ave., Chicago.

Wisconsin Concrete Products Association; **A. P. Kuranz. Secre**tary-Treasurer, 425 E. Water St., Milwaukee.